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Virginia Institute of Marine Science Forty-Seventh Annual Report

Virginia Institute of Marine Science

Forty-Seventh

1988 Annual Report

Virginia Institute of Marine Science

School of Marine Science

The College of William and Mary in Virginia

About the Cover: Seed clams raised at the
Eastern Shore Laboratory

Forty-Seventh

1988

Annual Report

for the period ending

June 30, 1988

Virginia Institute of Marine Science
School of Marine Science
The College of William and Mary in Virginia

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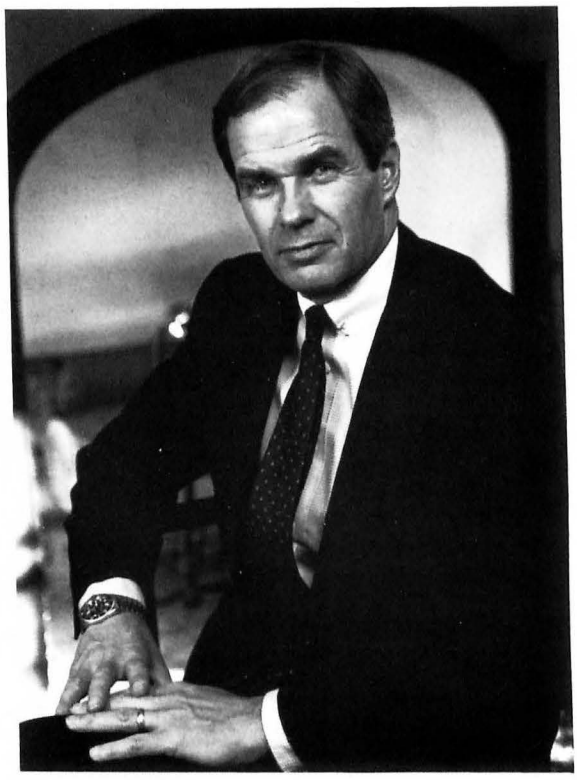
President's Letter



The Honorable Gerald L. Baliles
Governor of Virginia
State Capitol
Richmond, Virginia 23219

Dear Governor Baliles:

It is my pleasure to submit this forty-seventh Annual Report of the Virginia Institute of Marine Science/School of Marine Science of the College of William and Mary covering the year ending June 30, 1988.

Service to the Commonwealth of Virginia and its citizens continues to be the hallmark of the Institute. It is gratifying to note that as the work of the scientists at VIMS receives increasing attention, nationally and internationally, they continue to be excited about their role in the Commonwealth's efforts to preserve and manage the resources found in the State's tidal waters.

The impact of diseases on our Bay oysters has long been an area of interest at VIMS. The diseases and their impacts as well as ways to lessen disease impacts are being actively investigated with the goal of aiding Virginia's oyster industry.

As our coastal areas continue to develop, there is increasing pressure to better understand how our coastlines behave and to respond, where appropriate, with remedial actions. Significant progress is being made in both basic and applied research concerning the movement of sand between beaches and shallow water areas. Additionally, other studies have found substantial sand reserves that can be used to nourish eroding public beaches.

A major collaborative effort took place at VIMS in January of 1988 with 20 scientists from ten universities converging at the Institute to study two frozen coelacanths. These prehistoric looking fish, thought to be extinct until 1939, caused a great deal of excitement in the scientific community and received national news coverage.

Significant progress was made on the establishment of a Chesapeake Bay National Estuarine Research Reserve System in Virginia. Also the close working relationship between Marine Advisory Services and the seafood industry resulted in advances for the scallop, hard clam, and soft-shelled crab industries.

This report represents the last annual report to be produced by the Institute. With the 1988-90 biennium VIMS will adopt a biennial format for future reports.

Sincerely,

Paul R. Verkuil

Paul R. Verkuil
President

THE COLLEGE OF WILLIAM AND MARY
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VIRGINIA INSTITUTE OF MARINE SCIENCE
SCHOOL OF MARINE SCIENCE
ADMINISTRATION

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Michael Castagna . . . . . Assistant Director and Scientist-in-Charge of Eastern Shore Laboratory
Robert J. Huggett . . . Assistant Director for Division of Chemistry and Toxicology
Robert J. Orth . . Assistant Director for Division of Biological and Fisheries Sciences
L. Donelson Wright . . . . . Assistant Director for Division of Geological and Benthic Oceanography
Bruce J. Neilson . . . Assistant Director for Division of Physical Oceanography and Environmental Engineering

MARINE SCIENCE DEVELOPMENT COUNCIL

The Marine Science Development Council is an advisory body composed of leaders from Virginia's business and industrial communities who are interested in the continuing vitality of VIMS and its role in advising managers of Virginia's marine and estuarine natural resources. The primary function of the Council is to advise the Dean/Director of the Institute on planning and implementation of research and advisory services programs as they relate to the private sector.

Additionally, the Council advises the Institute on its private sector initiative program. This program is directed toward assisting VIMS in securing private resources to accomplish its goals.

The membership of the Marine Science Development Council includes the following persons:

Mr. George W. Roper, II, Council Chairman
Marine Safety Consultants/
Tidewater School of Navigation
Norfolk, Virginia

Dr. Wallace W. Atwood, Jr.
Former Director
Office of International Relations
National Academy of Sciences
White Stone, Virginia

Mr. C. C. Ballard
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Mr. Louis N. Dibrell, Jr.
Former Executive Vice President
Dibrell Brothers, Incorporated
Danville, Virginia

Mr. Frederick V. Ernst
Group Vice President - Kraft Products
Chesapeake Corporation
West Point, Virginia

Mr. Bruce C. Gottwald
President
Ethyl Corporation
Richmond, Virginia

Mr. Emory A. Gross
President
Fire Suppression Systems
Virginia Beach, Virginia

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Richmond, Virginia

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J. H. Miles & Company, Inc.
Norfolk, Virginia

Mr. William C. Monroe, A.I.A.
Caro, Monroe, Liang- Architects
Newport News, Virginia

Mr. Joseph R. Neikirk
Executive Vice President
Administration
Norfolk Southern Corporation
Norfolk, Virginia

Mr. J. I. Oatts
Executive Vice President
Virginia Power
Richmond, Virginia

Mr. F. Farrell Sanders, Director
Technical Services
Newport News Shipbuilding
and Dry Dock Company
Newport News, Virginia

Mr. Charles G. Thalhimer
Richmond, Virginia

Mr. Guilford D. Ware
Crenshaw, Ware & Johnson
Norfolk, Virginia

Captain J. Maury Werth, U.S.N. (Ret.)
Former Superintendent of the
U.S. Naval Observatory
Hagerstown, Maryland

Mr. Scott C. Whitney, Professor of Law
George Mason University and
Director, Institute of Law and Public
Health Protection
Arlington, Virginia

Mr. George A. Zahn, Jr.
Consulting Engineer
Gloucester, Virginia

Highlights

Dr. Frank O. Perkins, Dean/Director

Established by the Commonwealth in 1940 as the Virginia Fisheries Laboratory, the Virginia Institute of Marine Science (VIMS)/ School of Marine Science has expanded to become an internationally-recognized research, education, and public service institution in the field of marine science.

VIMS has its principal campus just across the York River from Yorktown. This location on an important estuary with easy access to the Chesapeake Bay and the nearby Atlantic Ocean provides the Institute with an ideal base for performing its teaching and research activities. A second, smaller campus at Wachapreague houses the Eastern Shore Laboratory and is strategically situated for work on the embayments, salt marshes, barrier beaches, and coastal waters of the Eastern Shore.

The Institute has a faculty of 72 full-time members, supported by a comprehensive library and a modern computer center. Under the aegis of the College of William and Mary, the School of Marine Science offers the graduate degrees of Master of Arts and Doctor of Philosophy in Marine Science and has an enrollment of 105 students from several states and foreign countries.

RESEARCH

◆ Coelacanths at VIMS! Such was the word across the country in January when about twenty scientists from ten universities converged for a historic opportunity to apply state-of-the-art methods to a postmortem of this living fossil. Using CAT Scan and Nuclear Magnetic Resonance Imagery, modern genetic techniques, and advanced chemical analyses, the team performed studies in gross morphology, physiology, biochemical genetics, parasitology, and the presence of man-induced pollutants. As a result of a competitive proposal, the specimens were awarded to the study team by the Explorers Club following collection by the Explorers Club and the New York Aquarium in the Comoro Islands near Madagascar.

◆ Oysters spawn in the summer, at a time of high biological activity in our estuaries. Depressed dissolved oxygen in the lower part of the water column is one frequent response to high biological activity. How do oyster larvae respond to that stress? Laboratory studies disclosed a surprising tolerance of larvae to low dissolved oxygen levels with even metamorphosis being able to proceed under highly stressed conditions of low oxygen.

◆ Depletion of dissolved oxygen is one response to nutrient enrichment via the oxidation of organic materials. How do the animal communities living in and on the estuarine sediment floor cope with this situation? The York and Rappahannock tributary estuaries offer contrasting situations to study these impacts; the York exhibits fortnightly reaeration while the Rappahannock tends to remain oxygen depressed in the deeper waters. Studies underway

offer the opportunity to establish the relationship between the intensity and duration of hypoxia and the response of the fauna.

◆ Utilizing State and federal funding sources, appreciable effort was devoted to tracing the pathways of nutrients within the Chesapeake Bay and its tributaries. In order to model the consequences of nutrient control strategies, the flux of these materials to the bottom must be understood. Stations to measure water column flux to the bottom were established in the Bay stem and lower York River.

◆ Having successfully demonstrated the technology to produce hatchery-reared oyster larvae for remote setting, attention is being directed to testing field nursery techniques which favor fast growth and reduced mortality. Comparisons are being made between tray and trestle systems in different water column settings, bottom pallets and upwelling tanks. These studies will assist the industry in the application of hatchery capabilities.

◆ Submerged aquatic vegetation has been shown in VIMS studies to be a very important shallow water habitat for recruitment of the juvenile blue crab. Laboratory and field studies strongly suggest that crab megalopae actively select the substrates on which they will settle. Current research is directed toward understanding the mechanisms settling crabs use to discriminate between substrates.

◆ Progress continued in tracing the effects of toxic chemicals in marine organisms. These efforts included examining the metabolites of polynuclear aromatic hydrocarbons (PAH), effects of sunlight on PAH toxicity to fish, and the response of the cellular immune activity of fish to toxicants. Additional efforts examined the toxicity response of bivalve larvae to estuarine water samples taken (over time) from 20 stations throughout the Virginia tributaries to determine if dissolved chemicals are effecting larval growth and development.

◆ Understanding the dynamics of fine grained sediment resuspension and deposition progressed on two fronts; instrumented observations within estuaries and along the ocean front, and design of advanced instruments. An annular flume capable of experimentally determining field *in situ* erosion and deposition characteristics has been designed. Another sensor package which can be embedded in soft mud beds to measure motion, shear strength, and pore-water pressure was developed.

◆ Continuing development along our coast lines imposes ongoing demands for a better understanding of how our coastlines behave; this understanding is the basis for prediction. Significant progress was made in both basic and applied research. Coupled with ongoing studies, these findings should elucidate how sand moves between the beach and the shallow shelf. Other investigations discovered vast nearshore sand resources suitable for nourishing eroding public beaches.

ADVISORY

◆ Sea scallops are the most valued seafood landed in Virginia. Marine Advisory Services has provided support which is changing long-held perceptions of the fishery and the basic biology of the sea scallop. This work is effecting the regulatory schemes for the mid-Atlantic region. Additionally, product handling studies will likely increase product profitability.

◆ As a result of a coordinated approach by management agencies, industry, and the team work between VIMS research and Marine Advisory personnel, the State regulatory agencies have granted approval for the containerized relaying of hard clams. This system reduces mortality, provides a better market product, and increases profitability.

◆ Marine Advisory Services continued to provide leadership toward a strong soft-shelled crab industry. The resulting production of soft crabs continues to expand. Technical advances in closed system design provided to industry have decreased mortalities and increased unit capacity.

◆ The Bay Team, marine advisory specialists in elementary and secondary education, provided programs for 50,000 students in Virginia's schools. The Bay Team is an integral part of the Chesapeake Bay Restoration and Protection Program and provides educational programs designed to help students understand the Chesapeake Bay ecosystem and the importance of individual and government management practices for a clean, wholesome Chesapeake Bay.

◆ Wetlands advisory group personnel received 1,906 applications for shoreline alteration permits during 1987-1988 and responded to many requests for pre-application advice.

EDUCATION

◆ A total of 21 degrees were awarded in Marine Science during the 1987-1988 academic year. Ten individuals received the Doctor of Philosophy degree and 11 the Master of Arts degree.

◆ Dr. Malcolm O. Green was the initial recipient of the John M. Zeigler Outstanding Student Achievement Award. Dr. Green, a student in Geological Oceanography, was awarded a Ph.D. in Marine Science during this past year. His dissertation topic was entitled "Low-Energy Bedload Transport by Combined Wave and Current Flow on a Southern Mid-Atlantic Bight Shoreface." Dr. Green is the recipient of a post-doctoral research fellowship with the Department of Earth Sciences, University of Cambridge, United Kingdom.

◆ Dr. L. Donelson Wright was the recipient of the first Faculty/Staff Outstanding Research Award. Dr. Wright is a Professor of Marine Science and Assistant Director for the Division of Geological and Benthic Oceanography. He is a member of the Geological Oceanography subfaculty.

◆ The faculty of the School of Marine Science developed and adopted the following statement on the aim of the School:

The aim of the School of Marine Science of the College of William and Mary is to provide excellence in graduate education to students pursuing careers in marine science. The academic program is closely interwoven with the mandated research and advisory programs of the Virginia Institute of Marine Science and this linkage is considered one of its major strengths. Students benefit from the mix of pure and applied science found in the Institute's research program. Objectives of the School's program are to provide a fertile environment capable of producing high quality marine science scholars and disciplined professionals oriented to management issues. Graduate studies leading to the Master of Arts and Doctor of Philosophy degrees are offered within a comprehensive academic program which allows all students the opportunity for close interaction with faculty involved on a day-to-day basis in research and advisory activities.

FINANCIAL MANAGEMENT AND ADMINISTRATION

◆ State funded activity amounted to $9.9 million during fiscal year 1988, as compared to $9.6 million during fiscal year 1987.

◆ The Institute's financial records for the preceding fiscal year (1987) were audited by the State's Auditor of Public Accounts. The Institute continued to receive an unqualified opinion with a few management comments aimed at improving internal controls.

◆ The State's Higher Education Equipment Trust Fund again provided much needed supplemental funding for state-of-the-art educational and research equipment. In fiscal year 1987-1988 VIMS received $117,000 from the fund which was used to acquire a toxicology laboratory control and monitoring system, a wave recording device, a liquid scintillation counter, a high purity water system for chemistry/toxicology, and a personal computer work station.

Research Feature

Clam Farmers Beat a Path to the Eastern Shore Laboratory

Michael Castagna, Associate Director and Scientist-in-Charge of Eastern Shore Laboratory

For the past fifteen years, would-be clam aquaculturists from all over the world have been making their way to the VIMS Eastern Shore Laboratory (ESL) in Wachapreague to learn the niceties and necessities of clam cultivation. The once-a-year course in clam aquaculture, organized and taught by Assistant Director and Scientist-In-Charge Michael Castagna, lasts but three days (about fifteen hours). It is nonetheless intense, a distillation of nearly thirty years of painstaking research by Castagna and his Wachapreague staff. However, the program is but one of many endeavors undertaken at the College of William and Mary's northeastern-most location.

Originally built in 1962 to research the parasitic oyster disease MSX, the Eastern Shore Laboratory has, in 1988, evolved into a complex of deceptively modest buildings that house some of the world's most advanced research programs in the aquaculture, habits and lifecyles of the class of marine organisms known as "bivalves"—otherwise recognized by the more common-language names of clam, oyster and scallop. Importer of research specialists and exporter of the results of bivalve research, the work of the ESL has attracted national and international attention and the critical praise of the scientific community.

One of the focal points of the facility is the main laboratory containing office, computer and laboratory space, as well as a small library with an extensive collection of current aquaculture and marine science journals.

The building's computer system is connected via modem to the main VIMS campus at Gloucester Point, permitting instantaneous exchange of information and research data. Experiments are carried out on bivalve breeding literally down the hall in the wet lab; bivalve physiology and chemistry experiments can be conducted in a room immediately adjacent to, but separated from the wet lab. A glass partition permits two-way visual and electrical communication between both sections.

Close by the main laboratory is the ESL machine shop. There staff technicians handle every variety of mechanical repairs, including design and construction of fiberglass tanks, carpentry, repair of power equipment, and maintenance of VIMS boats, trucks and cars. Visiting marine biologists and students are lodged in the 28-person ESL dormitory a few yards away from the main laboratory. A computer room, small laboratory, a classroom that doubles as study and lounge, and large kitchen are at the disposal of dormitory visitors.

But it is a group of buildings across the street where much of the Eastern Shore Laboratory's recent work in clam aquaculture has been advanced.

BUILDING A BETTER BIVALVE

Begun as an experimental clam-farming operation in 1973, VIMS's clam aquaculture program at ESL has steadily refined its procedures. In 1988, using seventh generation stock bred (beginning in 1973) for size, fast growth and hardiness, ESL staffers grew three million clams to "seed," or juvenile, size. Of those, 2.87 million were sold commercially to hatcheries or clam

Jean Watkinson checks the temperature of water in a larval container at the Eastern Shore Laboratory.

Hard clams

farms (proceeds go directly to VIMS), donated to Virginia watermen to replenish stock or given to VIMS or other scientists for research purposes. Of the remainder, 100,000 were "planted"—placed in shallow water to grow to mature adult size—and 30,000 selected and planted as future breeding stock.

Economic opportunities for astute clam aquaculturists are many, both in Virginia and the United States at large. While Michael Castagna and his ESL team have contributed a great deal to basic bivalve research, perhaps their greatest accomplishment is the development of practical, results-oriented procedures for the growing of clams.

Clams are quite fertile (each female can yield about 24 million eggs a year). In addition to the high fecundity rate, the selection of robust spawning clams is essential to the successful production of seed. Using its own select stock, ESL artificially induces spawning in its hatchery from April through July. Spawning is usually carried out in a trough of filtered seawater containing 50 broodstock clams. Spawning is induced by the raising or lowering of water temperature and the introduction of a killed suspension of gonadal products stripped from a wild clam. Fertilization of female eggs by male sperm takes place within a few minutes.

Shortly after fertilization, the egg-seawater suspension is drained from the spawning trough and poured through a series of sieves arranged in descending sizes. Eggs are sorted by size: because larger eggs develop into more successful larvae, the smaller eggs are discarded.

The fertilized eggs are then put in fiberglass or plastic containers filled with seawater filtered through polyprophylene bag filters. The filtered seawater is sometimes exposed to solar radiation to stimulate production of the phytoplankton that is the source of food for the rapidly maturing clams. Every other day the water is drained from the containers and the larvae are collected on sieves arranged in descending sizes. When seawater containing the larvae is poured through the sieve system, the smallest, slowest-growing and non-growing larvae are discarded. The remaining larvae are subsequently returned to a clean container filled with filtered sun-exposed seawater.

The clams continue to grow and mature attaching to the sides and to the bottom of their containers. Within 8 to 12 days of spawn, the clams can be rinsed from these containers, concentrated, and moved from the hatchery to the nursery. During the nursery phase, the clams are grown from post set to a size large enough for field planting.

The clams are moved to the nursery where they are placed in fiberglass trays with a plastic standpipe to adjust the water depth. Depth is kept relatively shallow to ensure good distribution of food, and a sieve is placed below the outlet to catch smaller clams should they wash away (these can be rinsed back into the tray). Bag filters reduce the amount of silt, detritus, fouling, predators and food competitors that enter the trays from pumped-in seawater. (Once the clams reach one to two millimeters in length, the filters become impractical and are eliminated.)

Growing clams held at high densities often compete with one another for food and may also become diseased. When a reduction in growth rate indicates overcrowding, the number of clams per container is reduced or the flow rate of seawater is increased. The clams can also be separated by size—smaller clams at higher densities, larger clams at lower densities.

If daily inspections reveal gaping clams, empty shells or the appearance of spots of black mud, then bacterial infection has set in. The solution: antibiotics or sodium hypochlorite. Clams are collected on a sieve, immersed for one hour in ten liters of medicated seawater, then rinsed and returned to clean trays.

Fouling can become a problem. Sea squirts, mussels, and marine worms are but a few of the organisms transported into the trays by flowing seawater. They affect clams by competing for food, space and oxygen; some even smother the small clams by attaching to or entangling them in tentacles or trailing threads. For clams less than one millimeter in size, fouling is reduced by the use of bag filters or by draining and air-drying for one hour daily.

For those clams above one millimeter in size, fouling is controlled by draining the clam troughs once every seven to 10 days and flooding the container with fresh tap water. The fresh water is allowed to remain standing for one half hour. Seawater can then be pumped back in with no further treatment for the next seven to 10 days. Most of the fouling organisms cannot survive freshwater immersion and the clams show no ill effects from the treatment.

The length of time the clams spend in the nursery is dependent on a number of factors, among them the growth rate and the desired grow-out size. Most clams remain in the ESL nursery from June through October. If clams have been placed in submerged trays and are not overcrowded, they can be left for about a year before being moved to the final grow-out phase.

Field grow-out, as the term implies, means moving the clams to natural waters. Space and food requirements increase geometrically as clam size increases. As clams grow larger, it becomes less economical to grow them in containers or to pump sufficient quantities of seawater to furnish enough food for survival or additional growth. They are therefore distributed in prepared beds, trays or floats and placed in shallow coastal waters.

To make the endeavor profitable, it is necessary to use seed that is large enough to survive and mature. The data shows that seed eight millimeters in size or larger survive in greater quantities when planted in net-protected natural

areas in Virginia. When planted in trays or screened containers, smaller sizes—four to six millimeters—often do almost as well.

The ESL work has demonstrated the effectiveness of a three-phase clam farming operation. The hatchery phase is relatively dependable and economical using existing technology, but the most difficult and costly step appears to be the nursery phase. Growing seed clams to a size large enough to be successfully reared to market size in the field is labor intensive and requires unremitting attention to detail; diligent prevention of disease and fouling is an absolute necessity. Last but not least, effective predator exclusion—with nets or protected trays—is also critical in the field grow-out phase.

Michael Castagna estimates that he has provided information on ESL techniques to over 100 commercial clam farms in the continental United States, including seven in the state of Virginia. Of those, 80 have sent one or more of their employees to Castagna's annual course on clam aquaculture.

1988 PROJECTS

In addition to its extensive clam aquaculture and research efforts, ESL hosted 14 different student groups from universities across the country in 1988. ESL coordinates field trips to the barrier islands of the Eastern Shore to enable student marine biologists, oceanographers and geologists to study ecological systems, marine species interaction and coastal processes.

In 1988, a number of academic researchers visited the ESL facility, including a Chinese marine biologist interested in larval bivalve identification through the use of photomicrography. Another, from Chile, monitored the differences in swimming behavior of clam larvae in relation to salinity layers found in seawater.

ESL's own research projects for 1988 included experiments in gas supersaturation in seawater to determine harmful bivalve effects, predation patterns and biological control of that predation, the "setting" or growth-to-maturity rates of wild clams on the Eastern Shore, as well as a number of projects involving scallops and oysters.

The ESL researchers also confirmed the results of an innovative Canadian study that examined ways to inexpensively store late-spawning juvenile clams over the winter months. ESL staffers found that clams less than six millimeters in size can be packed on paper towels that have been dampened by seawater, put in airtight plastic containers and then placed in ordinary refrigerators at 6 degrees Centigrade (42 degrees Fahrenheit). Ninety-eight percent will survive. When removed and put back in their trays or containers, over 90 percent of the the larval clams will survive and continue to grow until they are planted in the field.

Such an emphasis on the intersection of rigorous research methods and practical applications has long been a hallmark of the work done at the Eastern Shore Laboratory in Wachapreague. If past indications are any guide, aquaculturists and marine scientists will, for years to come, make the trek to Wachapreague to learn the complex ways of the bivalve.

Graduate student Beverly Baker

Graduate Education

Twenty-one graduate degrees were awarded to graduates of the School of Marine Science in 1987-1988. Ten individuals were awarded the Doctor of Philosophy degree and eleven received their Master of Arts degree.

The Outstanding faculty /staff award for 1988 was awarded to Dr. L. Donelson Wright, Professor of Marine Science, for excellence in research. Dr. Wright is a member of the Geological Oceanography subfaculty and is an Assistant Director and Head of the Division of Geological and Benthic Oceanography.

The John M. Zeigler Outstanding Student Achievement Award was awarded for the first time to Malcolm O. Green a Ph.D. candidate in Geological Oceanography.

An internal review of the academic program was initiated by the faculty of the School of Marine Science. In addition, the faculty of the School developed and adopted a statement on the Aim of the School of Marine Science which reads:

"The aim of the School of Marine Science of the College of William and Mary is to provide excellence in graduate education to students pursuing careers in marine science with an emphasis on estuaries and the coastal ocean. The academic program is closely interwoven with the mandated research program of the Virginia Institute of Marine Science and this linkage is considered one of its major strengths. Inasmuch as the research and advisory programs of the Virginia Institute of Marine Science emphasize applied research in consideration of management needs, students in the allied School of Marine Science benefit from a mix of pure and applied science. An objective of the SMS program is to provide a fertile environment capable of producing high quality marine science scholars as well as disciplined professionals oriented to management issues. Graduate studies leading to the Master of Arts and the Doctor of Philosophy degrees are offered within a comprehensive academic program which allows all students the opportunity to have close interaction with faculty involved on a day-to-day basis in research and advisory activities.

Malcolm Green was the first recipient of the John M. Zeigler Student Achievement Award.

STATISTICAL PROFILE FOR THE ACADEMIC YEARS 1985, 1986, AND 1987

All students who registered in the fall of 1985, 1986, and 1987

Ph.D.				M.A.			
Male		Female		Male		Female	
1985	39	1985	10	1985	36	1985	34
1986	46	1986	9	1986	33	1986	26
1987	40	1987	8	1987	26	1987	27

	Students Registered	Students on Leave	Total
1985	119	20	139
1986	114	20	134
1987	101	21	122

Resident Status:	In-State	Out-of-State	Foreign
1985	59	45	15
1986	51	41	22
1987	38	42	21

Student Support for Fall 1987

Assistantships	79
Fellowships (GPOP awards and foreign scholarships)	4
Internships	0
William and Mary Teaching Assistantships	0
William and Mary Workship	3
TOTAL	86

Marine Science Degrees Awarded by the College of William and Mary for the Past Five Academic Years

Academic Year	Masters	Doctorates
1983-1984	6	12
1984-1985	10	9
1985-1986	5	8
1986-1987	13	10
1987-1988	11	10

Matriculations in the School of Marine Science for the Past Five Academic Years

Academic Year	Applications	Number Admitted	No. of New Students Who Matriculated
1983-1984	70	56	19
1984-1985	77	44	13
1985-1986	78	45	25
1986-1987	70	32	16
1987-1988	52	32	7

DOCTORAL DISSERTATIONS IN MARINE SCIENCE COMPLETED DURING THE 1987-1988 ACADEMIC YEAR

DE LISLE, PETER FRANCIS
The Effects of Salinity on Cadmium Toxicity to the Bay Mysid, *Mysidopsis bahia* Molenock. (Morris H. Roberts, Jr.)*

FRISCH, ADAM A.
Development, Test and Application of a New Method of Particle Shape Analysis Based on the Concept of the Fractal Dimension. (John D. Boon, III)

GREEN, MALCOLM O.
Low-Energy Bedload Transport by Combined Wave and Current Flow on a Southern Mid-Atlantic Bight Shoreface. (L. Donelson Wright)

KIM, CHANG SHIK
Interaction of Long Waves and Nearshore Barred Topography - A Mechanism for Bar Migration. (L. Donelson Wright)

MOUSTAFA, MOHAMED ZAKI
Advanced Turbulence Closure Models and Their Application to Buoyant and Non-Buoyant Flows. (Carl F. Cerco)

MUNROE, THOMAS ALLAN
A Systematic Revision of Atlantic Tonguefishes (*Synmphurus*: Cynoglossidae:Pleuronectiformes) with a Preliminary Hypothesis of Species Group Relationships. (John A. Musick)

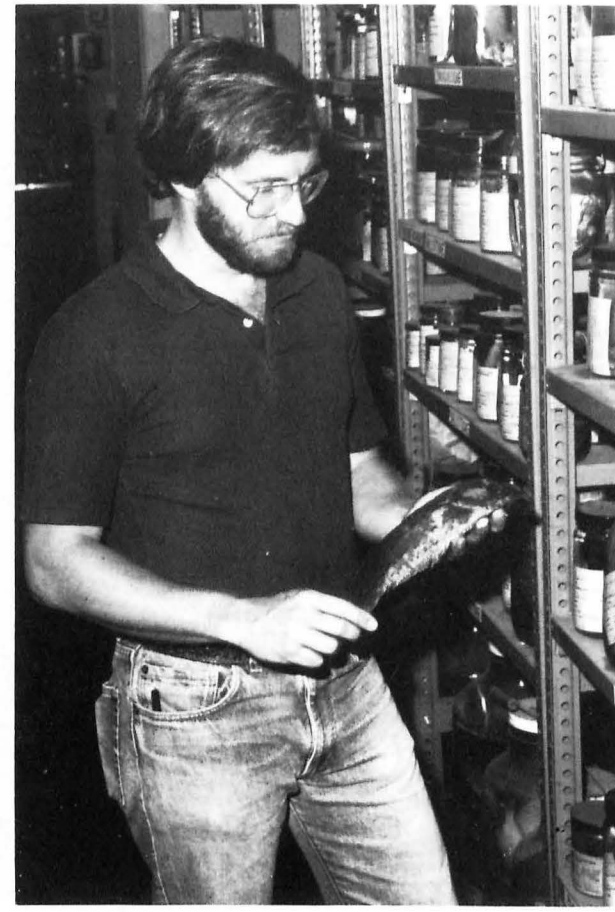
RYER, CLIFFORD H.
Studies of Pipefish Foraging in Simulated Seagrass Habitats. (Robert J. Orth and Richard L. Wetzel)

STAUFFER, THOMAS BENNETT
Sorption of Nonpolar Organics on Minerals and Aquifer Materials. (William G. MacIntyre)

UNGER, MICHAEL A.
Investigation of Tributyltin Water/Sediment Interactions. (Robert J. Huggett)

VAN TINE, ROBIN F.
Aspects of the Ecology of Estuarine Light with Special Reference to Seagrasses of the Chesapeake Bay: Measurements and Models. (Richard L. Wetzel)

* Major professor(s) named in parentheses



Doctoral degree recipient Thomas Munroe

MASTER OF ARTS THESES IN MARINE SCIENCE COMPLETED DURING THE 1987-1988 ACADEMIC YEAR

ARMSTRONG, MICHAEL PATRICK
Life History of the Goosefish, *Lophius americanus*. (John A. Musick)

BOWEN, BRIAN WILLIAM
Population Structure of the White Perch, *Morone americana*, in Lower Chesapeake Bay as Inferred from Mitochondrial DNA Restriction Analysis. (John A. Musick)

CAMPOS MAIA, BERNARDITA
Swimming Responses of Larvae of Three Mactrid Bivalves to Different Salinity Gradients. (Roger L. Mann)

COX, CARROLLYN
Seasonal Changes in Fecundity of Oysters *Crassostrea virginica* (Gmelin) from Four Oyster Reefs in the James River, Virginia. (Roger L. Mann)

HUGGETT, DOUGLAS VERNON
A Trophic Resource Analysis of Dominant Benthic Macrofauna of the Lower Chesapeake Bay. (Robert J. Diaz)

JABLONSKY MOUSTAFA, MARY SUE
Swash Induced Zonation of a Foreshore Sediment Size Distribution. (John D. Boon, III)

JOHNSON, HARRY D., JR.
Potential Fish Egg Predation by *Mnemiopsis leidyi* Determined by Hydrography at the Chesapeake Bay Mouth. (John E. Olney and John J. Govoni)

SAVAGE, REBECCA JO
Modes of Longshore Variability in the Development of a Bar - Trough Morphology. (L. Donelson Wright)

SKRABAL, STEPHEN ANDREW
Clay Mineral Distribution and Source Discrimination of Holocene Sediments in Lower Chesapeake Bay, Virginia. (John D. Boon, III)

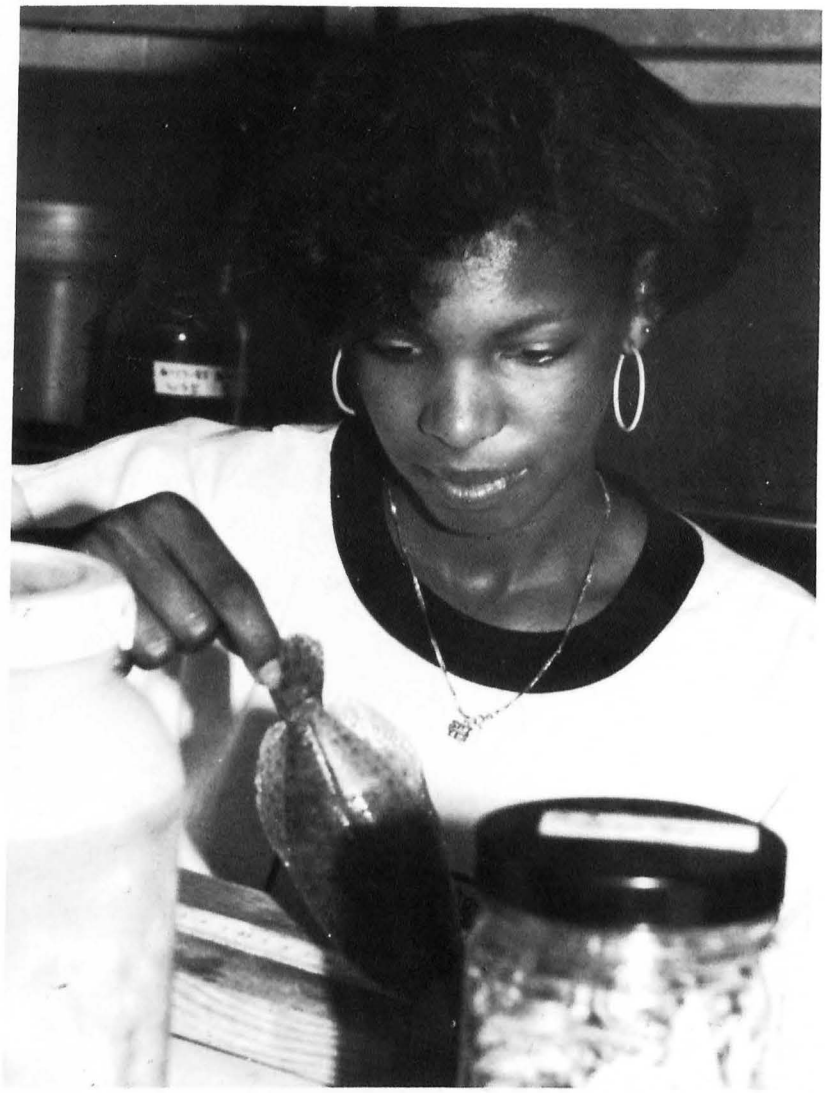
SKRABAL, TRACY EANES
System Response of a Nourished Beach in a Low Energy Estuarine Environment, Gloucester Point, Virginia. (Robert J. Byrne)

ZOBRIST, ERIK CHRISTIAN
The Influence of Post-Settlement Mortality on Recruitment Patterns in a Soft-Bottom Habitat. (Robert J. Diaz)

Masters degree recipients Bernardita Campos Maia (right) and Carrollyn Cox.

Summer Intern Program

The summer intern/research aide programs serve a number of purposes. They provide the opportunity to expose undergraduates to marine research at an early stage in their academic careers. These programs also allow the School of Marine Science to target groups that are underrepresented in the marine sciences for orientation towards marine science, and finally they provide assistance to the Institute scientists in the collection of field and laboratory data. These programs have received support from the Exxon Foundation, the U.S. Department of Education Minority Institution Science Improvement Program (MISIP), the Virginia Environmental Endowment Program (VEE) and Union Camp Corporation. The MISIP grant is a cooperative project between the School of Marine Science and Hampton University administered by Hampton University.



Summer intern Vanessa Hunter

SUMMER INTERNS AT VIMS 1987 AND 1988

1987

Roderick B. Buck
Hampton University
Exxon
Henry E. Calvert
Jackson State University
Exxon
Kateric J. Kirby
University of Michigan
Exxon
Sylvester R. Young
Hampton University
Exxon
Kim Waymer
Hampton University
MISIP
William H. Nuckols, III
College of William and Mary
VEE
Rachel Whalen
Mary Washington College
VEE
Carrie S. Burreson
Christopher Newport College
VEE

1988

Vanessa D. Hunter
Norfolk State University
VIMS
Stacy A. Nelson
Jackson State University
VIMS
William H. Nuckols, III
College of William and Mary
VEE
C. T. Barnard
College of William and Mary
VEE/Union Camp
Molly Minnick
Mary Washington College
VEE/Union Camp
Carrie Burreson
Christopher Newport College
VEE/Union Camp
Linda Moncure
Christopher Newport College
Union Camp
Lisa Rice
Gloucester High School
Union Camp

Visiting Scientist Program

Visiting scientist John Simpson (second from left).

In a continuing effort to broaden and share its own research knowledge, the Virginia Institute of Marine Science/School of Marine Science has in recent years begun a program to attract nationally- and internationally-known scientists to visit VIMS on a regular basis. The program continued during 1987-1988 with the visits of three experts from various fields of study. Such specially-selected individuals from leading centers of research bring valuable new ideas and techniques from other institutions, and contribute to improving the capabilities of the Institute.

As a leader in the United States in estuarine and coastal research, the Institute also believes that it has much to offer from its own ongoing research projects. Each visit anticipated under the program is expected to offer mutual benefits to the Institute and the visiting scientist.

The program is competitive, with selection of recipients based on: 1) accomplishments of the individual; 2) applicability of the scientist's areas of expertise to research being conducted at VIMS; and 3) potential to develop further the Institute's centers of excellence in sedimentology, pathobiology, toxicology, environmental chemistry, and other areas of directed research in the Institute research plan. The Visiting Scientist Program is funded under grants from Sovran Bank, N.A. and the Edmondson Foundation.

PARTICIPANTS IN THE 1987-1988 VISITING SCIENTIST PROGRAM

Dr. John H. Simpson
School of Ocean Studies
University College of North Wales
Gwynedd, United Kingdom
Physical Oceanography
(1 month)

Dr. George G. Brown
Department of Zoology
Iowa State University of Science and Technology
Ames, Iowa
Fish Reproduction Studies
(6 months)

Dr. Arieh Wishkovsky
Department of Microbiology
The University of Maryland
College Park, Maryland
Fish Immunological Studies
(2 months)

Library

VIMS library reading area.

A major event in the Library this year was the personnel change in the Bibliographic Services. Librarian Janice Meadows resigned in May to accompany her husband, a VIMS graduate, to his new position at Cambridge University, England. We will be ever mindful of her outstanding role in the design of the new library.

An extensive search for a Bibliographic Services Librarian was successful. We are most pleased with our selection of Marilyn Lewis, who brings to us experience as a Cataloging Librarian at the University of Tennessee and nine years of marine science library work including the Head Librarian position at the South Carolina Marine Resources Center.

The Library received $15,000 from VIMS private funds to purchase books. The ever increasing periodical costs squeezes our materials budget so we can no longer meet our current book needs.

The Chesapeake Bay Bibliography, a current on-line database, continues to provide literature searches for persons seeking specific information on the Bay. We developed a thesaurus from the key words used in the CBB to improve both the indexing and retrieval of information. A library network to facilitate the distribution and exchange of Bay information is planned for the future.

A complete set of National Wetlands inventory maps of Chesapeake Bay was acquired to help researchers and managers determine wetlands locations, sizes and types.

Also obtained were copies of the entire map collection of the present and potential productivity of Baylor oyster grounds in Virginia.

Library Holdings at the End of FY 1987-1988:

Number of periodical titles - 800
Bound volumes (periodicals and books - 39,605
Other holdings (maps, charts, etc.) - 3,274

Interlibrary Loans FY 1987-1988:

Provided to other libraries - 274
Received from other libraries - 728

Computer Center

Computing capabilities at VIMS have undergone significant expansion in the past decade. In the late 1970's, computing service was provided by a small slow computer using card input and printed output. Major calculational power for modelling or statistical analysis was provided on the main William and Mary campus in Williamsburg, 16 miles away from VIMS.

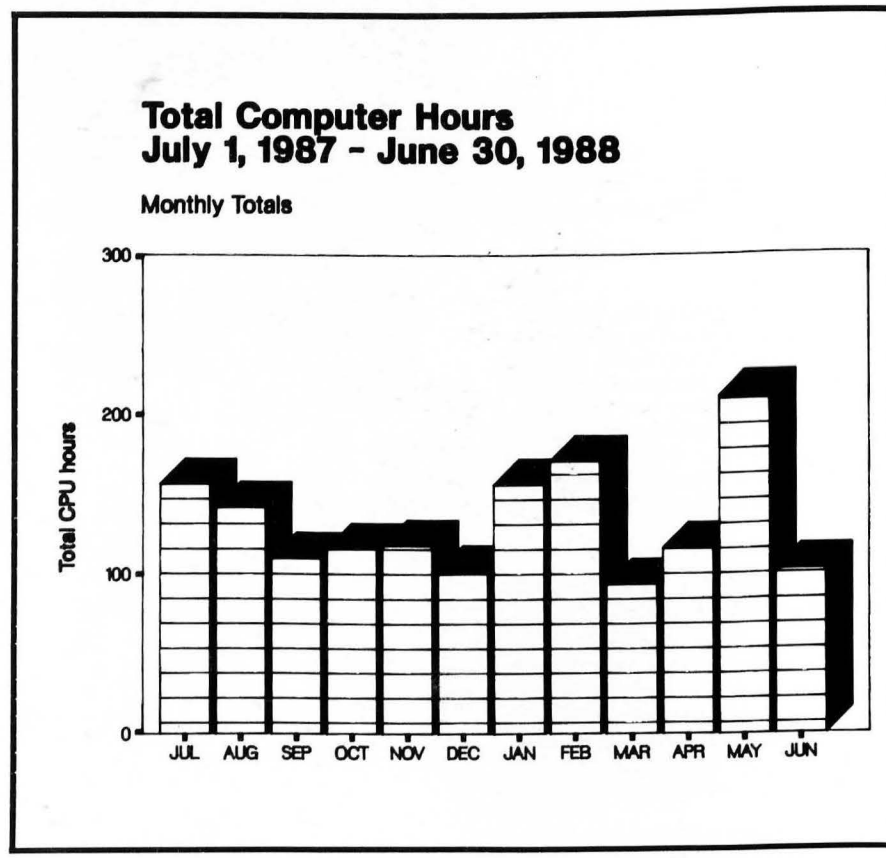
The Institute now has a powerful interactive computer serving more than 50 simultaneous users throughout the campus or remotely. Programs and data are stored "on-line", immediately available for users—no more boxes of cards to be carried to the Computer Center with the danger of inadvertent shuffling or dropping in the mud or snow!

The use of computer graphics has increased. This is of great value, not only in production of presentation-quality graphs but also in interpretation of data at all stages of an investigation. The plots can be displayed on video terminals or drawn by pen plotters driven from the computer.

The use of microcomputers at VIMS has increased greatly over the last ten years. More than 100 are now installed throughout the campus. The Computer Center has encouraged the acquisition of microcomputers and serves as a clearing-house for individual applications and utility software.

The Computer Center's plan over the past ten years has been to distribute computing service throughout the campus. The computing power of the PRIME is available at terminals all over the campus and through "dial-up" lines. Although the introduction of microcomputers has distributed individual computing power and a certain amount of data storage, these machines continue to form a portion of the overall computer network.

The kind of person using the computer has also changed. As the computer has become increasingly available, non-programmers have come to use "canned" programs such as those for statistical analysis or graphical display. The software packages available on the PRIME include word processing, statistical analysis, database management, graphical display and map production. Some of the software packages have been purchased, but some have also been developed by Computer Center people. An important task of the Center is to provide programming and system development support to the Institute.



COMPUTER HARDWARE AND SOFTWARE

The PRIME 9955 II is configured with 16 megabytes of main memory, 2076 megabytes of disk storage, 64 ports for terminal input and two magnetic tape drives. Printed output is available from the high-speed line printer located in the computer room or from a number of letter-quality printers located around the Institute. Graphics display is available from a variety of terminals. Graphical output is produced on a Nicolet/Zeta 8, eight-color pen plotter with a paper width of 12" and a single-pen Houston Instruments DP-3 with a paper width of 22".

The following software packages are installed: SPSS^{x}, SPSS Graphics, SAS Basic, SAS/Graph (statistics); 20/20 (spreadsheet); WordMARC (word processing); INFO, SIR/DBMS, SIR/FORMS, SIR/SQL (database management); IMSL (mathematics library); SURFACE II, DATAPLOT (graphical data display). Language compilers include FORTRAN 77, Pascal, PL/1, COBOL. Communications software allows terminal emulation and error-checking data transfer between personal computers (IBM compatible, Macintosh) and the PRIME.

At present there is a total of 202 computer terminal input stations installed throughout the Institute. These are connected to the 64 input ports on the PRIME by means of an Equinox data switch. The switch also allows the connection of terminals to

computing systems other than the PRIME. Some administrative users can connect their terminals to computers on the Williamsburg campus for financial and accounting work.

COMPUTER CENTER STAFF

A Computer Center is not composed only of hardware and software; people form a equally necessary component. The VIMS Computer Center has a staff of highly dedicated and motivated people. None of them received formal "computer" training, but their backgrounds include ocean engineering, physical oceanography, geological oceanography and elementary particle physics. They have always viewed the computer primarily as a tool rather than an end in itself. We believe that this attitude has contributed to a positive and fruitful relationship between the Computer Center and the VIMS user community.

The services provided to the Institute by the Computer Center staff may be classified as consulting, advisory and educational. The consulting work ranges from a "quick fix" of a user-developed application to a commitment of several months on a designated project. Through these consultative activities, the members of the staff become closely involved with the Institute's research projects and are frequently co-authors in publications. Similarly, the advisory service ranges from responding briefly to numerous "walk-ins," to a continuing commitment to provide advice and direction to long term projects.

A major advisory role is played in the area of data management as is described in the following section.

DATA MANAGEMENT

The Computer Center assumes both active and supporting roles in managing the scientific data resources of the Institute. The VIMS Data Archive, maintained by the Center, is a repository of research and monitoring datasets (some of which date to the nineteenth century). Among these are the VIMS Ferry Pier Monitoring data (to 1947), oyster spatfall data (to 1947), finfish abundance, and hydrographic datasets containing over 1.5 million data records. In addition, the Center serves as liaison for exchanging data with other agencies. VIMS often shares data with agencies and research institutes around the Bay region such as the Chesapeake Biological Laboratory, the Chesapeake Bay Institute, the Smithsonian Institution, the EPA Chesapeake Bay Program, the Virginia Marine Resources Commission, the Virginia Water Control Board and the Virginia Department of Game and Inland Fisheries.

In a supporting role, Center staff participate in the design and implementation of databases used by the various research programs and administrative divisions. One such effort is the Chesapeake Bay Bibliography, operated by the VIMS Library.

Another departmental database is the Wetlands Permit recording system for tracking modifications to the Commonwealth's tidal wetland resources. The database resides on the VIMS central PRIME computer and will be used for the wetlands management program in Virginia.

The VIMS Trawl Survey program received assistance from the Center in the form of several new data collection and analysis tools, including NEKLEN, a length-frequency plotting program written by Kevin Kiley, and BAYRAND, a random-sample generating tool written by Gary Anderson.

VIMS has been participating in the Virginia Rivers Inventory. Many of VIMS holdings will be converted into the ARC/INFO Geographical Information System (GIS) software obtained by the Center in the spring of 1988. The ARC/INFO system allows for the storage, retrieval and analysis of map data. A GIS system provides a powerful tool for examining complex spatial relationships by performing automated analysis of map data.

The PRIME computer system also does its share of data collection. An environmental monitoring system logs water temperature and conductivity in the York River at the end of the VIMS pier and air temperature, wind speed and direction, rainfall and solar insolation on the roof of Byrd Hall. Each day, at midnight, the PRIME automatically interrogates the system to dump the day's data which is then stored on the PRIME system.

IMAGE PROCESSING AND ANALYSIS

The past decade has seen a great increase in the use of computers to operate on the information contained in all kinds of images: photographs, microscope and telescope fields of view, satellite images.

The first project using image processing was a collaboration between the Computer Center and Dr. J. D. Boon, a VIMS geologist, to study and classify the shape of quartz sand grains. The software for the detection and tracing of the grain outlines in the field of a microscope was developed by Computer Center analyst R. J. Lukens. Since the classification was based on statistical parameters, it was essential to measure many thousands of grains. Without the computer system this would not have been a feasible experiment.

A cooperative effort between VIMS and the Commonwealth Data Base led to the acquisition of an International Imaging Systems Model 75 Digital Image Processing System. The system has been used for a wide variety of applications including: surface feature analysis of aerial and satellite images; animation of hydraulic and mathematical flow model data; enhancement and spatial analysis of sediment core photographs; three-dimensional bathymetric modeling and display; and time lapse studies of oyster spat development.

CONCLUSION

Computing at VIMS has evolved in a similar fashion to many other institutions. Computing power and facilities have been distributed to the users but a degree of communication among users has been maintained. Future development will include the installation of Local Area Networks in individual buildings all linked together and with the central large computer through an Institutional network. In this way, data, programs, peripherals and computing power may be shared among all users throughout the Institute.

Vessels Support Center

Steve George (left) and Danny Gouge onboard the R/V BAY EAGLE.

The Institute answers its varied requirements for research vessels by centralizing all of its boats into a service center. This organization has produced optimum cost benefits in the delivery of platform support to field research efforts. The active fleet is comprised of twenty vessels, ranging in size from 14-foot jon boats to the 65-foot R/V BAY EAGLE.

The primary goal of the Vessels Support Center is to provide the caliber of scientific support that enhances the integrity of the Institute's field programs and to perform consistently at such a high standard. The elements that govern such performance are vessel equipment, facilities and personnel. Efficiency depends upon the proper balance between these three key elements. Today's Vessels Support Center is continually strengthening its ability to achieve the goal that it strives toward, by very carefully managing the resources which are invested in new equipment, better facilities and additional personnel.

During the previous five years, much has been accomplished within the Center to upgrade the fleet's condition and its capabilities. Twelve trailerable boats have been systematically replaced with new custom built vessels; each one designed to meet specific scientific requirements. These boats are operated by members of the Institute's scientific staff. At least 100 individuals have served as an operator in charge of a trailerable vessel during the past year. Being capable of accomplishing many scientific missions without the expense of larger vessels and their professional crews, the Institute receives tremendous cost benefits in much of its field work.

The five major vessels in the fleet are constantly being modified or outfitted to accommodate the ever-changing demands of marine research. The electronic age continues to permeate every facet of our vessels' operation. As soon as one new system is implemented, another comes under consideration. Fortunately, the technical capabilities that VIMS maintains within its staff of vessel captains, mates, and shop specialists allows virtually all of the new technology to be adapted to the vessels without the cost of contractors.

Many of the past year's highlights for the Vessels Support Center have occurred in the area of facilities improvements. The marina and its entry were dredged to a depth of six feet and new mooring facilities were constructed. Two major bulkheads were repaired and strengthened by the addition of new catwalks. A tractor and a crane were both salvaged from the State's surplus property facility. Each was renovated to perform specific functions within the marina site. A welding facility has been created within the maintenance shop. Storage locations have been developed for many important items, which has greatly improved the efficiency of daily operations. Finally, a marine radio system was installed, which enables people onboard our vessels to be patched directly into the telephone system. This capability has eliminated the losses that result from passing messages through a third party.

Research Vessel Fleet Composition

Length	Age	Name	Configuration/specialty	Speed/propulsion
65'	1980	*Bay Eagle*	Aluminum hull, larger groups & equipment projects	16/450HP diesel (2)
44'	1972	*Langley*	Spacious lab rigged for physical oceanography	10/200HP diesel (2)
42'	1972	*Capt. John Smith*	Lobster boat rigged for biological sampling	16/350HP diesel
36'	1972	*Phalarope*	Cabin cruiser used as a wetlands base station	16/210HP gasoline (2)
35'	1980	*Ulysses*	Deep-vee design set up for hydrographic work	20/255HP diesel (2)
26'	1977	*Telemachus*	Large cockpit and forward cabin, good freeboard	18/100HP gasoline (2)
26'	1968	*Libra*	Small cabin cruiser, overnight surveys & tracking	16/190HP gasoline
			Trailerable Boats	
26'	1982	*Osprey*	Garvey type hull, enclosed cabin, power winches	25/155HP outboard
26'	1982	*Marsh Hawk*	Garvey type hull, enclosed cabin, power winches	25/155HP outboard
26'	1982	*Heron*	Garvey type hull, enclosed cabin, power winches	25/155HP outboard
24'	1982	*Skimmer*	Deep-vee design, high speeds/slack water runs	48/235HP outboard (2)
23'	1976	*Plover*	VHLC's Sea Ox - open skiff, on loan to VIMS	35/150HP outboard
21'	1986	*Oystercatcher*	Forward cabin, hydraulic winch, dredging boat	25/170HP gasoline (I/O)
21'	1986	*Teal*	Fiberglass open skiff with self bailing decks	30/155HP outboard
21'	1986	*Gannet*	Fiberglass open skiff with self bailing decks	30/155HP outboard
21'	1988	*Egret*	Fiberglass open skiff with self bailing decks	30/155HP outboard
21'	1988	*Pelican*	Fiberglass open skiff with self bailing decks	30/155HP outboard
19'	1967	*Albatross*	Rigged w/push net for alosa survey program	30/ 65HP outboard (2)
19'	1973	*Kingfisher*	Cathedral hulled, walk through windshield	25/170HP gasoline I/O
18'	1987	*Sandpiper*	Fiberglass open skiff with self bailing decks	35/ 65HP outboard
18'	1987	*Widgeon*	Fiberglass open skiff with self bailing decks	35/ 65HP outboard
18'	1987	*Sea Gull*	Fiberglass open skiff with self bailing decks	35/ 65HP outboard
14'	1967	*Oysterette*	Boston Whaler used by hatchery - manual start	15/ 35HP outboard
14'	1982	Jon boat	Four person, aluminum vee-bottom - elect. start	25/ 25HP outboard
14'	1982	Jon boat	Four person, aluminum vee-bottom - elect. start	25/ 25HP outboard
14'	1983	Jon boat	Four person, aluminum vee-bottom - elect. start	25/ 25HP outboard
14'	1983	Jon boat	Two person, aluminum flat bottom, w/o trailer	15/ 10HP outboard
14'	1985	Jon boat	Two person, aluminum flat bottom, w/o trailer	15/ 10HP outboard
14'	1987	Jon boat	Two person, aluminum flat bottom, w/o trailer	15/ 10HP outboard
12'	1984	Zodiac	Inflatable boat used to support SCUBA diving	25/ 25HP outboard
10'	1984	Zodiac	Inflatable boat used to support SCUBA diving	15/ 15HP outboard

Six dual axle and six single axle trailers are presently in active service. Three diesel powered and four gasoline powered generators are being maintained. One tractor and two diesel powered cranes are also maintained by the vessels staff.

Dissection of the larger of two coelacanth specimens, donated by the Explorers Club to a research team based at William and Mary, was performed by Craig Sullivan (North Carolina State University) (left) and Jack Musick (VIMS).

Research

John Boon readies a directional wave and current meter for deployment.

During 1983 the Virginia Institute of Marine Science inaugurated a comprehensive ten-year research plan designed to address the most important management issues facing the Chesapeake Bay system. The research activities reported here center around programs identified in the ten-year plan. These encompass fifteen research programs and eight monitoring programs, focusing on this overall goal: "To conduct general and applied research for the purpose of providing timely and accurate information to the Governor, General Assembly, State and local agencies, industries and citizens of the Commonwealth of Virginia regarding utilization, conservation and enhancement of the resources, both living and non-living, of the Chesapeake Bay system and the coastal waters of the Commonwealth."

The principal uses of this plan are:

- to identify the scope of research needed to meet the requirements of the Commonwealth, and in particular to focus on those problem areas needing the most urgent attention;
- to provide a planning mechanism for efficient programming of State funds, and to identify those research areas where particularly aggressive effort should be placed in seeking extramural funding;
- to ensure that any pursuit of extramural funding is controlled and within the context of a long-range coherent plan; and
- to identify the additional personnel and equipment resource needs which must be obtained for satisfactory completion of the coherent plan.

PROGRAM I
INVESTIGATE THE FISHERIES OF VIRGINIA AND FACTORS AFFECTING FLUCTUATIONS IN ABUNDANCE.

Fish trawled from the Elizabeth River are sorted by Paul Gerdes.

Bivalve Ecology. The focus of work in the bivalve ecology group is to obtain a greater understanding of the ecology and life history of commercially valuable mollusk resources. Our major effort concentrates on the James River oyster fishery, particularly factors influencing temporal and spatial (both intra- and interannual) variability in recruitment of oysters into the seed oyster beds, and the subsequent growth and survival of those oysters. The most tractable means of addressing the issue of long-term stability of the seed beds is to examine its component problems. During 1987 we focused research efforts on the questions of: 1) egg production by broodstock oysters; 2) settlement of planktonic oyster larvae to the benthos; and 3) post settlement losses to predators.

Our effort focusing on egg production by the larger broodstock oysters in the James has taken an increased meaning in the past three years due to the increasing impact of the oyster disease organisms *Haplosporidium nelsoni*, commonly known as MSX, and *Perkinsus marinus*, commonly referred to as "Dermo." Three successive drought summers in 1985, 1986 and 1987 have resulted in more saline waters progressing further upstream in the James River and other subestuaries of the Chesapeake. The diseases, which are limited in distribution by salinity, have also moved upstream and now extend to the Wreck Shoal area of the James River. The separation, by some considerable distance from the nearest region of abundant oysters suggests that the seed bed area in the James River is a self-contained system—that is oysters recruiting to the seed beds originate from spawning in the seed beds. Clearly, maintenance of adequate broodstock is essential. Throughout the 1985-87 period a continuing decline in broodstock size due to disease, especially in the downriver area, has been noted. Results of a time-series transect study along the length of the James River, in which we examined the number of oysters per square meter of bottom, the size distribution of oysters, their sex ratio and relative fecundity (number of eggs per female oyster) and the state of ripeness of those eggs, indicated that the upriver area around Horsehead Rock contributed more eggs than any of the other areas examined. The high numbers of oysters (over 450 per square meter in some samples) at this site more than offset the reduced fecundity associated with smaller mean oyster size. In 1987 we also examined the possibility that unexploited, "deep" water oyster stocks on the fringes of the commercially exploited rocks might contribute to the broodstock in the river. These stocks represent a very small percentage of the resource. They undoubtedly contribute to spawning but they cannot be relied upon to sustain the James seed oyster fishery.

Oysters spawn eggs and sperm into the water column. Fertilization occurs and the free swimming, microscopic larval form remains in the water for a period of 2-3 weeks. On completion of the larval stage, oyster larvae develop a foot for crawling, sink to the bottom and lose their swimming organ. Oyster larvae settle and metamorphose to the attached benthic fauna on other oysters or oyster shells. It is this behavior that is responsible for the building, over geological time, of oyster reefs. We have examined the influence of low dissolved oxygen content of the water on larval metamorphosis. Oyster larvae have proven remarkably tolerant of this condition. Prior to metamorphic competency, larvae actively swim away from low oxygen regions, even when exposed to less than 0.5 mg/L of oxygen! Animals can successfully metamorphose even if such conditions are maintained for several days—a small percentage even survive after eight days at such stressful levels, a situation probably rarely encountered in the field.

The oyster reefs of the James River are abundantly supplied with endolithic blue green algae—microscopic, filamentous algae that bore into the shell layers, and indeed the shells of live oysters on the oyster rocks. Although studied for over 100 years these algae are poorly understood. In field studies we found endolithic blue geen algae to be present throughout most of the middle and upstream portion of the James River seed oyster beds. Only the presence of boring sponge further downstream appears to prevent occurrence in that location. In laboratory tests we examined the influence of the presence of endolothic blue green algae on oyster larval settlement and metamorphosis and found it to have no deleterious effect.

Clearly, oyster larvae are much more hardy than we had originally considered; however, some demonstrated tolerance to environmental adversity is no excuse to environmental abuse. The success of larval recruitment and subsequent growth is an end product of continuing maintenance of good environmental conditions. Thus, any contribution in this arena is valuable.

Post settlement oysters may occur in significant numbers; however, losses to predation can be very significant. In 1987 we focused on predation losses to blue crabs. Under optimal conditions (for the crab) these predators can have devastating effects on oyster survival. A large crab can consume over 30 oysters per day with ease. Various refuges from predation pressure exist. As oyster size increases, the oysters become susceptible only to larger crabs. For example, crabs of 60-80 mm carapace width were unable to prey upon oysters of approximately 35 mm shell length—unfortunately, crabs grow throughout the summer as do the oysters so the latter cannot easily "outgrow" the former. Male crabs have different cheliped (claw) morphology which allows them to open larger oysters than a female crab of similar size. Large male crabs are particularly destructive, and it is not until oyster density decreases to such a level as to make further foraging and predation unprofitable, oysters attain a size refuge at 30 mm shell length, or temperature decreases below 14°C, that blue crab predation becomes minimal.

The James River will remain the focus of both the market and the seed oyster fishery in Virginia for at least the coming five years. As such it warrants our continuing research and monitoring efforts. Disease pressure causes the fishing effort to be concentrated in an ever decreasing area; however, market prices ensure that even reduced catches remain profitable. Focus on market oysters has drastically reduced availability of seed for replanting. Both market and seed fisheries are potentially unpredictable and unstable at this time and are cause for continuing concern.

Climate and Fisheries. Research continues on the effects of climate variability on recruitment of summer flounder, croaker and spot. Spawning and larval dispersal in the mid-Atlantic Bight was investigated during two cruises aboard the NOAA ship FERREL. Estuarine field collections, begun in 1986, continued monthly throughout the year. To determine nursery areas of newly recruited fish, Wachapreague and Sand Shoal Inlets on the seaside of the Eastern Shore, Occohannock Creek on the bayside of the Eastern Shore, and the mouth of the York River on the western shore of the Chesapeake Bay were sampled. Within each site, habitats were divided and sampled according to depth (shallow vs. intermediate vs. deep) and substrate (sand vs. mud). Initially, croaker predominately recruit to deeper channels and flounder and spot to shallow mud habitats. Depth and substrate preferences appear to change over time. This research shows that the waters behind the Virginia barrier islands, as well as within the Chesapeake Bay, provide important nursery habitat for newly recruited commercially and recreationally important finfish. The gear used was appropriate for collecting postlarvae and juveniles, sampling newly recruited croaker 5-10 mm, flounder 15-20 mm and spot 20-25 mm.

The research effort to describe the habitat, in terms of depth and substrate, of early juvenile summer flounder, *Paralichthys dentatus*, in Virginia estuaries is nearing completion. All field work is finished. An analysis of data collected from September 1986 to July 1987 revealed that early juvenile summer flounder 14-152 mm (total length) were most abundant in shallow (1-2 m) mud-bottom habitats, areas that have not been frequently sampled in past research efforts. This study represents the largest collection of early juvenile summer flounder from Virginia estuaries. It also supports a hypothesis proposed over 20 years ago that the sounds of North Carolina, Chesapeake Bay and bays on the seaside of the Eastern Shore of Virginia are the primary nursery grounds for summer flounder.

Flounder recruited in fall 1986 to seaside locations, indicating recruitment from northern areas, but they did not recruit at all in fall 1987, probably due to offshore wind-driven transport of larvae. Flounder recruited in spring 1987 to locations within the Chesapeake Bay, indicating transport from a southern location. Recruitment for spring 1988 is almost non-existent and indicates poor year class strength.

Spot showed good recruitment in the spring of 1987 and again in 1988 to bay locations, indicating transport from the south. Qualitative observations show recruitment in the spring following episodes of southerly winds. Spot are hypothesized to spawn near or south of Cape Hatteras with the larvae transported northward by the currents. A study was begun in spring 1988 to identify the physical mechanisms responsible for the transport of spot to the Chesapeake Bay. Ichthyoplankton samples and temperature/salinity data were collected onboard the NOAA ship FERREL during February. Larval spot (<5 mm) have been found in samples from near Cape Hatteras supporting the premise of a spawning site near Hatteras. A preliminary study of movement of spot through the mouth of the Chesapeake Bay was also initiated. Selection of sample sites and feasibility of different types of sampling gear were examined in preparation for an intensive sampling program in spring 1989.

Seining for juvenile flounder.

In both 1986 and 1987, croaker recruited first and at a smaller size in seaside estuaries, indicating transport from nearby shelf areas as hypothesized; however, transport was good in fall 1986 but poor in fall 1987. Ichthyoplankton samples from a November cruise aboard the NOAA ship FERREL have been partially sorted. Several croaker larvae, increasing in size from near Cape Hatteras north to Chincoteague, Virginia, were found. This suggests northward transport of larvae from a southerly spawning site as was suggested by the analysis of fall wind patterns. Winter temperatures were marginal both years, forecasting an average year class for summer 1987 and a poor year class for summer 1988.

Chesapeake Bay Finfish Stock Identification. Current studies are funded by the U.S. Fish and Wildlife Service and passed through the Virginia Marine Resources Commission (VMRC) (Wallop-Breaux) or directly from the Atlantic States Marine Fisheries Commission. This work includes stock identification using electrophoretic (biochemical and genetic) and morphological (body proportions) measurements of bluefish and weakfish, and electrophoretic measurements of flounder. Preliminary analyses of first year morphometric results suggest that two separate stocks of bluefish could be present in the Chesapeake Bay during spring.

Anadromous Fishes. Research on anadromous fishes (those which spawn in fresh waters and mature in ocean waters) during this past year focused on estimating the fishing effort expended for American shad, alewife, blueback herring and striped bass, and the tagging and releasing of striped bass in the James and Rappahannock rivers.

Effort data are a basic ingredient in many mathematical models concerning exploitation and mortality rates, and stock size. Pound net effort was estimated from frequent aircraft flyovers, and gillnet fishing effort was collected by observers in small boats and from logbooks kept by cooperating fishermen. Effort data were also of value in population dynamic studies on nonanadromous species. These data in conjunction with the monitoring data (see section on monitoring) for anadromous species were used to estimate: 1) rela-

tive abundance (catch-per-unit-of-effort) by year class; 2) year class biomass and the cumulative biomass of a year class in a fishery; 3) exploitation and mortality rates; and 4) growth rates from back calculations on annuli of otoliths and scales.

The objectives of the mark-recapture studies are to: 1) evaluate exploitation within and outside the Chesapeake Bay region; 2) assess coastal migrating patterns of these species; 3) assess the degree of fidelity to the river-of-capture in subsequent spawning seasons; and 4) contribute to the present age- growth and size at maturity data base. The ultimate goal of all federal and state agencies concerned with anadromous fishes is the development and implementation of rational management plans to restore and enhance anadromous fish stocks. Toward this end, the major goal of the VIMS program is the development of stock assessment models that will give Virginia fishery managers state-of-the-art quantitative tools.

Crustaceology. Fiscal year 1987-1988 was a year of continuing program development with an overall objective of understanding the patterns and regulation of abundance, distribution and survival of commercially important crustaceans and mollusks. Funds from the Commonwealth of Virginia, National Science Foundation, Smithsonian Institution, Earthwatch - Center for Field Research, Bahamas Undersea Research Foundation and Centro de Investigacions de Quintana Roo (Mexico) supported a diverse assortment of field and laboratory investigations. In Chesapeake Bay, research programs emphasized: 1) predator-prey dynamics involving the blue crab, benthic prey (e.g., soft-shell clam) and epibenthic fish such as spot; 2) recruitment patterns and processes of postlarval and juvenile blue crabs; 3) quantitative surveys of the blue crab in the York, James and Rappahannock rivers; 4) modelling of blue crab population dynamics, including fishery models; 5) analysis of blue crab stomach contents from various areas in the lower Bay as a function of prey availability; and 6) development of a bay-wide Fishery Management Plan for the blue crab as part of the Chesapeake Bay Agreement. International research programs, which provide scientific expertise to underdeveloped nations lacking qualified scientists, focused on stock enhancement of the queen conch and spiny lobster by reduction of mortality agents.

Mainstem Chesapeake Bay Fish Research. Funds acquired from the Chesapeake Bay Stock Assessment Committee were used to initiate, in January, trawl studies of the species and size compositions and spatial/temporal distributions of fishes in mainstem Chesapeake Bay waters throughout Virginia. Fishes were identified as to species, counted and weighed by species, and measured for length. Preliminary results suggest species compositions show large variation over time, less variation spatially. Abundant species in winter/spring have included bay anchovy, silversides, several herrings and American shad, northern searobins, spotted hake, and spot.

Pound Net Research on Marine/Estuarine Fishes. Contacts have been continued to develop working relationships with pound net fishermen on which to build programs to collect basic life history/population dynamics data on adult marine and estuarine fishes. Proposals have been submitted to initiate such studies on a large scale.

Flounder Research. The summer flounder tagging study got off to a resounding start in 1987-88. More than 5,000 flounder were tagged and released in Chesapeake Bay, off Wachapreague and Virginia Beach. These studies will lead to better understanding of flounder stocks, migration, mortality, age and growth. This information will be used to make recommendations for a revised size limit on summer flounder in Virginia.

Shark Research. The shark program again worked closely with the Virginia Beach Sharkers, a recreational fishing group. The Sharkers donate all sharks captured in their annual tournament to VIMS for study. VIMS scientists remove vertebrae for age determination and examine feeding habits and sexual development in sharks landed at the tournament. These data are used to complement data derived from sharks captured as part of the long-term VIMS long-line project which has made more than 200 long-line collections in the Chesapeake Bight since 1973. This year data collected from these programs over 12 years on shark diets were analyzed and diets of several species were compared. In addition to life history studies on sharks, VIMS scientists continued their studies of hydrodynamic lift and associated drag in sharks, tuna and billfishes. New findings suggest that body surface areas (which effect friction drag) may be easily estimated by an equation employing length and girth which are much easier to measure than area itself. Studies of deep-sea sharks and chimaeras were expanded with acquisition of a large series of very rare specimens collected as deep as 3 km off the Canary Islands. Current studies are examining the hypothesis that maximum depth of occurrence of sharks is controlled by energy availability.

A juvenile loggerhead sea turtle is returned to the ocean by Wendy Teas (left) and Cary Griffith.

Turtle Research. Research on sea turtles continued in 1987-1988. Efforts centered on tracking sea turtles with radio and sonic transmitters to study migration, surfacing behavior and movements. In addition, another turtle was tracked at sea for seven months with a transmitter monitored by satellite. This represents the longest successful sea turtle satellite tracking experiment ever accomplished. Aerial surveys were continued to obtain estimates of sea turtle standing stocks in Chesapeake Bay and coastal waters from Cape Hatteras to Chincoteague; stranded sea turtles were counted to monitor sea turtle mortality. Live turtles supplied by pound net fishermen were injected with oxytetracycline for aging studies and tagged with metal tags and released for migration studies. Close to 100 turtles, a new record, were supplied by cooperating fishermen. Results of our aging studies to date show that only one growth ring is deposited on the turtle humerus bone per year. Thus ring counts are probably an accurate indicator of age and loggerheads do not mature until 20-30 years of age. Studies on the effects of electromagnetic pulses (EMP) produced by the U.S. Navy's EMPRESS facility were conducted

with Navy support. Preliminary studies suggest that electromagnetic pulses alter magnetic material found within the heads of turtles. These studies are continuing and sea turtle populations are being monitored at the Navy's EMPRESS test site off False Cape, Virginia.

Ichthyology Museum. The VIMS museum fish collection continued to serve as a repository for scientific voucher specimens. In addition to specimen loans, gifts and trades to scientists all over the world, the collection is also used as a teaching aide by VIMS Advisory Services personnel. Museum curators also identified many fish specimens for the general public during the year. The most scientifically significant specimens in the museum's 20 year history, two coelacanths, were acquired in January. A team of distinguished scientists from around the United States assembled at VIMS to participate in visceral dissections of these specimens. Frozen coelacanth tissues have been sent to 50 scientists around the world for genetic and physiological analysis. In addition, the two VIMS coelacanths were subjected to C.T. scan and Nuclear Magnetic Resonance Imaging through the cooperation of Riverside Hospital in Newport News, Virginia. These modern techniques will allow us to learn much more about coelacanth morphology.

Gulf Coast Fishes. This work continues with emphasis in the past year on a complex of several Gulf of Mexico sea robin species. The two species most intensively studied to date, the bighead and Mexican sea robins, both appear to have life history/population dynamics patterns similar to other fishes of Gulf shrimp communities, e.g., they are small, short-lived, rapid in growth and have high mortality rates.

Microbiology of Shellfish and Shellfish Growing Areas. Research efforts focused on two major problem areas in shellfish microbiology. First, the scientific validity of the fecal coliform indicator used to classify shellfish growing areas, and second, the problem of shellfish closures in growing areas which are not impacted by known point sources of human sewage. Studies performed at VIMS and other institutions suggest that the fecal coliform indicator is an inadequate predictor of public health risk. Research continued on the role of environmental factors such as salinity, seasonal temperature and sediment on survival/abundance of the fecal coliform indicator. In addition to the indicator question, microbiologists sought and obtained funding to address the problem of shellfish closures in growing areas in the absence of known point sources of human sewage. This problem, identified by state, federal and industry groups as one of national concern, has significantly reduced harvestable growing area acreage by as much as 50 percent in some shellfish producing states. Basic questions which are being examined include: understanding the potential role of domestic or wild animals as sources of indicator bacteria and microorganisms pathogenic to humans; and the importance of precipitation, water table, suitability of soil types for septic systems, and land use on the microbiology of the receiving waters. Crucial to addressing the issue of animal pollution is the identification, assessment and development of methodology for the recovery of indicators which allow differentiation of human from animal sources of fecal contamination. Therefore, efforts focused on selection of candidate alternate indicators; detection in shellfish growing areas and adjacent watersheds; survival characteristics; and enumeration methodology. These investigations included both water column and sediment.

Participation continued in an EPA-sponsored shellfish feeding study to validate the predictive value of the current fecal coliform growing area standard and to evaluate alternate indicator organisms. Microbiologists were responsible for overseeing shellfish collection from approved local waters, aspects of microbiological processing, and transportation to University of North Carolina, Chapel Hill. Raw shellfish were then fed to volunteers who were subjected to a comprehensive epidemiological analysis to screen for verifiable enteric disease statistically different than in various control groups. This is the first study to be performed to quantitatively validate the public health significance of the current shellfish growing area standard.

Patrice Mason inspects a sample fraction resulting from gel permeation chromatography.

VIMS microbiologists continued to participate in the area of shellfish microbiology at the national level. The Microbiology Committee of the Interstate Shellfish Sanitation Conference (ISSC), a national group representing the industry, state and federal regulatory personnel, was chaired by a VIMS microbiologist. The assistance of Institute microbiologists was requested in the development of a National Shellfish Pollution Indicator Study proposal with relation to specific technical issues which included the identification of candidate indicators, and methodology and development of criteria for site selection. The Shellfish Branch of the Food and Drug Administration and the American Public Health Association (APHA) requested the assistance of Institute microbiologists in the publication of a new edition (sixth) of the APHA Laboratory Procedures for the Examination of Seawater and Shellfish. VIMS microbiologists presented a seminar addressing the survival of the fecal coliform indicator in estuarine waters at the 88th Annual Meeting of the American Society of Microbiology.

Experiments were conducted to examine the effect of layered packing depth on the purification of oysters subjected to containerized relaying. Following the demonstrated success of this process on the purification of clams, industry and state regulatory groups requested Institute microbiologists to perform this evaluation. Self-purification was examined with the fecal coliform indicator, *Escherichia coli*, and an F-specific RNA phage, a candidate alternate indicator. Results from two comprehensive experiments demonstrated the effectiveness of this process.

PROGRAM II
INVESTIGATE AND DEFINE THE DISTRIBUTION OF BENTHIC ANIMALS AND COMMUNITIES AND THEIR INTERACTIONS WITH THE BIOLOGICAL, PHYSICAL, AND CHEMICAL ENVIRONMENT.

Using a Smith-McIntyre grab, Roberto Llanso collects a sample of benthic invertebrates.

The objectives of this program are to evaluate biologically mediated physical and chemical interactions at the benthic boundary layer, to evaluate man-induced effects as they impact the benthic environment, and to evaluate the resource value of different bottom habitats. The objectives and many of the field operations of this program are closely interwoven with the Benthic Boundary Layer Program (Program XI).

Benthos and Water Quality. Benthic organisms have long been regarded as good indicators of water quality in aquatic habitats because of their sedentary life styles, taxonomic diversity and intimate association with the sediment-water interface. The stationary or limited mobility of some life stages (larvae among the insects and adults for most other taxa) ensures that benthic invertebrates are exposed to local environmental conditions without the option of escape open to other more mobile species. Life spans ranging from several months to years allow temporal integration of environment quality. There is a long history of using benthic macroinvertebrates from lake and pond systems to assess water quality. These efforts have culminated in the development of plans for simple, reliable assessment of water quality using ***in situ*** benthic assemblages.

In estuaries and coastal marine waters, benthic invertebrates have also received attention as indicators of environmental stress. Their utility has been limited by a number of factors including high natural variability, complex physical gradients, and difficulty in identifying adequate control sites. The resource value of benthic invertebrates, both as direct commercial species and through trophic links to other species, may be altered by changes in water quality. Using data from the VIMS Benthic Data Base and ongoing studies, we have evaluated the utility of traditional and newer methods for assessing environmental impact with benthic invertebrates. We developed a more practical approach for monitoring benthic communities and demonstrated its reliability with our data base. The new approach is based upon the observation that long-lived, deep-dwelling, large species form an important component of healthy benthic communities and are absent from severely stressed communities.

Effects of Low Dissolved Oxygen. In recent years we have begun to understand some of the processes which contribute to oxygen depletion in Chesapeake Bay and other coastal waters. Deep water oxygen reduction has been attributed to several processes: the development of a salinity gradient during the spring freshwater runoff, leading to water column density stratification; an increase in benthic respiration rates as water warms; and an increase of the organic detritus load reaching the bottom. Four objectives have been formulated to evaluate the response of the benthos to low dissolved oxygen and anoxia.

Objective 1. Document benthic community dynamics in relation to seasonal occurrence of low dissolved oxygen in the lower Chesapeake Bay and tributaries. We have identified areas in the Rappahannock and York rivers which vary in the intensity and duration of low dissolved oxygen in bottom waters. At some stations low dissolved oxygen in bottom water was a persistent feature during the summer of 1987, at others it was an intermittent phenomena, and at still others hypoxic conditions were recorded only once. The response of benthic macrofauna in terms of abundance ranged from near complete defaunation to no noticeable effects on densities. Analysis is ongoing with regard to functional group changes. The major contribution of these data may be in establishing a relationship between the intensity and duration of hypoxia and observable declines in the abundance of macrofauna.

Objective 2. Determine the impacts of low dissolved oxygen in bottom water on recruitment patterns of selected benthic species in the lower Chesapeake Bay and its tributaries. Major recruitment peaks for most species in this area are in the late spring-early summer with secondary peaks for some in the late summer-early fall. We have followed the arrival of new recruits at stations in the York and Rappahannock rivers and, to a lesser extent, in the mainstem of the lower Bay during the late summer-early fall of 1987. These samples are being processed on appropriately small sieve sizes to retain newly-recruited individuals. Though the processing and analysis of these samples are not yet complete, it is clear at this point that not only the intensity and duration of low dissolved oxygen, but also the timing of recruitment peaks in relation to intermittent low dissolved oxygen events, are important determinants of recruitment success.

Objective 3. Determine the effects of hypoxia on the availability of energy for transfer to higher trophic levels. Samples for the calculation of production of dominant benthic species during late summer and fall of 1987 have been collected and analyses are ongoing. Since growth of estuarine benthic organisms in this area is most rapid during the spring and summer, production estimates will be much enhanced by data to be collected during this summer (1988). Field samples have been collected in a manner which will permit determination of organism vertical distribution (numbers and biomass) within the sediments, an important component of energy availability to higher trophic levels. Field data on behavioral modification under oxygen stress were obtained photographically during August 1987 in the mainstem of the Bay near the Rappahannock River mouth. Photographs reveal infaunal polychaetes and burrowing cerianthid anemones in a moribund state on the sediment surface or body parts extended several centimeters above the sediment surface. At the time of this event, dissolved oxygen in bottom waters ranged from 0.0 to 0.9 mg/l.

Further, we have conducted preliminary laboratory experiments to evaluate the effects of hypoxia on the behavior of selected species. Behavioral responses of the bivalve *Macoma balthica* range from those which should increase siphon nipping by browsing predators (flaccid siphons on the sediment surface) to those which may reduce susceptibility to predation (retraction into sediments). Laboratory cultures of the numerically important polychaete species *Streblospio benedicti* have been established and experimental systems for maintaining them under varying oxygen levels are being developed. In summary, we are making progress towards determining how hypoxia affects the production, vertical distribution and behavior of several benthic species, and towards coupling these into an understanding of how low dissolved oxygen may affect energy availability to higher trophic levels.

Objective 4. Identify the signature of low oxygen events in surface sediments and determine if these events are preserved in the stratigraphic record. Box core samples, and surface and profile photographs have been collected at a variety of sites in the Rappahannock and York rivers and in the mainstem of the Bay. These samples provide records of the near-surface stratigraphy and sediment characteristics. Additional sampling efforts (seismic profiling and 3 m gravity coring) have been directed towards identifying an area within the Rappahannock River which is characterized by a long, continuous sediment accumulation so that historical trends in bioturbation can be evaluated. As a result of these activities, sites for intensive study during the summer of 1988 have been identified.

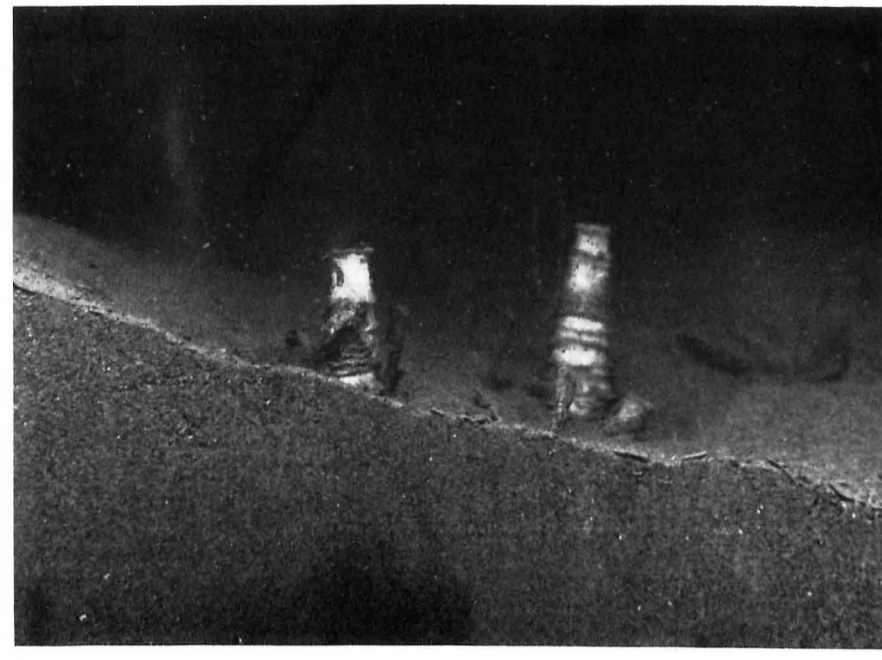
Remote Sensing of the Benthic Environment. Through the use of sophisticated underwater cameras, methods have been developed for evaluating the relative benthic habitat value of the bays' bottoms. The system is known as SPI, for Surface and Profile Imagery. It consists of a sediment profile camera that penetrates the sediment, providing photographs of subsurface sediment structures, and a standard underwater camera to photograph the surface of the bottom. Using both sediment profile and bottom surface cameras to provide a unique ***in situ*** view of the sediment-water interface, qualitative and quantitative data are obtained on its biological, chemical, and physical character. This ***in situ*** photographic approach and subsequent computer image analysis can quickly and cost effectively cover large areas of bottom defining biological, sediment fabric and energy gradients or other spatial patterns. The response of the bottom to natural or anthropogenic events (i.e., storms, high flows, dredged material disposal) through time can also be easily followed and recovery rates measured.

We have found there to be broad scale patterns in the bottoms of the Chesapeake Bay that are mainly related to sediment grain size and salinity. With the cameras we can also see how benthic organisms effect the structure of the sediments through burrowing and feeding activities.

Animal-Sediment Interaction. Studies of animal-sediment interactions constituted a major research effort during 1987-1988. The recent sediment record, as preserved in x-radiographs of sediment cores from over 350 locations in the Chesapeake Bay estuarine system, was evaluated for trends in biological community characteristics and for evidence of the types of physical processes operating within the estuarine benthic boundary layer. Much like the stratigraphic record preserved in rock formations, the near surface sediment record provides an integrated "snapshot" of recent (months to years) boundary layer processes. Results demonstrate that sediments in low salinity areas are physically structured when sediment accumulation is rapid, but biotic reworking is occasionally important in areas of fluctuating deposition or where erosion-deposition cycles occur. In high salinity areas of the estuary, where the fauna is characterized by an equilibrium type community, biotic sediment mixing prevails and sediments are highly structured by tubes and burrows. More detailed, concurrent studies of the fauna in these high salinity areas demonstrate that biogenic structure increases habitat heterogeneity and that the increased availability of microhabitat space results in an increase in species richness in the community.

Blue Crab Habitat Studies. Ongoing biological studies begun in 1987-1988 include investigations of blue crab ecology in the mainstem of the lower Chesapeake Bay. The blue crab, *Callinectes sapidus*, is of major commercial importance in estuaries along the Atlantic and Gulf coasts. The species is also a conspicuous component of the estuarine invertebrate fauna. Despite its obvious economic importance, some aspects of the blue crab's ecology are poorly understood. Early studies have focused on habitat use by overwintering crabs. Studies are now beginning that will investigate crab feeding and burrowing behavior at low temperatures and usage of dredging disposal sites and dredged channels as habitats.

A sediment profile photograph from the lower Chesapeake Bay shows parchment worm tubes.



PROGRAM III
DEVELOP AN UNDERSTANDING OF PLANKTON PROCESSES IN THE CHESAPEAKE BAY SYSTEM AND VIRGINIA'S COASTAL WATERS.

Bongo nets like the pair Steve Szedlmayer is working on are used for collecting fish eggs and larvae.

Innovative Technology and Methodology Development. Manual identification and enumeration techniques for plankton are slow, labor intensive, expensive and inadequate for modern research needs. Consequently, significant resources have been allocated to the development of innovative technologies and methodologies.

A comparison of the epifluorescent and Utermohl microscope techniques for enumerating natural estuarine plankton populations is underway with funding from the Virginia Environmental Endowment. The results of this study, which is being conducted in collaboration with Old Dominion University scientists and will be completed in late 1988, will be provided to Virginia's water quality managers who oversee the state's monitoring efforts.

A high resolution, underwater camera to photograph zooplankton was purchased in 1987-1988. The staff has successfully deployed this camera, along with conventional zooplankton sampling gear, in the Chesapeake Bay plume and in the James River. Further testing will determine the environmental conditions (such as plankton densities and water clarity) appropriate for this sampling approach. Funding has been solicited from agencies concerned with larval fish ecology.

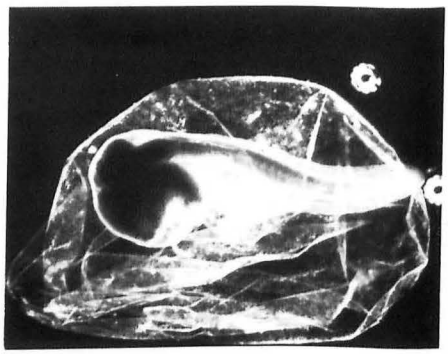
Considerable progress also has been made on the development of the color image analyzed fluorescence microscopy (CIAFM) system. Scientists now are using the CIAFM to measure cell size spectra and biomass of the microbial community in planktonic systems. In addition, funding has been requested to incorporate solid-state, charge-coupled devices into a comparable black and white image analysis system.

The primary goal of all three technique development efforts is to ensure that plankton research in Virginia is carried out with state-of-the-art methodologies. The data gathered using these technologies will not only be useful well into the 21st century, but also will allow scientists to gain new insights into processes controlling the plankton communities at the base of the food chain.

Chesapeake Bay Plume. A study of physical and biological processes affecting the distribution of larval fishes at the Chesapeake Bay entrance continues. The investigation, funded by the National Science Foundation, is cooperative with the University of Maryland and addresses the complex interactions between larval fishes, their principle food, predators and the physical environment. The study is based on the analysis of over 1200 biological samples and attendant hydrographic data collected in June and August 1985. A manuscript describing the effects of Bay mouth hydrography on potential fish egg predation by the lobate ctenophore *Mnemiopsis leidyi* is being prepared for formal publication. The study revealed how changing patterns of predation were related to water column stratification. A doctoral dissertation on the influence of the plume on ichthyoplankton community structure, larval fish distribution, growth and transport is in progress. The investigation will compare patterns of vertical distribution of larval anchovies and weakfish to similar observations of larval blue crab distribution in an attempt to compare contrasting strategies of estuarine retention.

Striped Bass Food Chain. Studies designed to examine trophic interactions in the striped bass developmental habitat include an investigation of seasonal zooplankton succession, an inventory of potential fish and invertebrate predators of striped bass eggs and larvae, a time-series analysis of striped bass egg mortality and spatiotemporal variability in patterns of survival of striped bass juveniles. Our primary objective is to describe the different factors affecting survival of striped bass eggs and larvae in an attempt to account for observed annual variability in juvenile abundance. A paper entitled "Potential predation by fish and invertebrates on early life history stages of striped bass in the Pamunkey River, Virginia" was recently published in the March issue of **Transactions of the American Fisheries Society**. The investigation determined the kinds and relative abundances of potential fish and invertebrate predators through field surveys during striped bass spawning periods, documented acceptability of striped bass yolksac larvae as a prey item through laboratory presentations to fish and invertebrates, established consumption rates of yolksac larvae under laboratory conditions of various prey densities and examined stomach contents of target fish predators collected on the spawning grounds.

Given the knowledge that a field of potential predators existed on the striped bass spawning grounds, a time-series study was conducted to provide a field estimate of striped bass egg mortality. During peak spawning activity 270 liters of a red fluorescent dye were released at the upper limit of a selected sampling area during high slack water. The dye was used as a tag to follow a parcel of water containing a population of eggs for two consecutive days. A total of 1,594 eggs was collected during the study. Egg densities at



A preserved striped bass egg.

positive stations ranged from 0.54 to 8.37 eggs/m^3 and approximately 88 percent of the eggs collected during the study were viable. These eggs were separated into eight developmental stages allowing identification of five different cohorts of known age. Instantaneous mortality coefficients were calculated for the five cohorts. The mean mortality estimate of 72.4 percent of all eggs spawned per day agreed with comparable results on other fish species. However, our results have revealed that biases due to physical processes such as advection and diffusion are not easily overcome and are a likely source of error in similar studies of pelagic egg and larval mortality.

An additional objective of the time-series study was to obtain data on residence time and transport of eggs in regions of the Pamunkey River that represent primary spawning sites. Dye was released during slack-beforeflood at the downstream entrance of a thoroughfare in Sweet Hall Marsh. Preliminary analysis showed that this channel served as a short-cut for tidal transport, delivering dye far upriver. The tagged water parcel did not return to the site of dye release during the following ebb tide indicating that channels in tidal freshwater marshes may act as a retention mechanism allowing eggs and larvae to remain in a favorable developmental habitat without being swept seaward during critical pelagic stages.

Sampling intended to describe spatio-temporal variation in survival of larval striped bass was initiated during the 1988 spawning season. Biweekly ichthyoplankton cruises were conducted from 4 April through 27 May to determine egg and larval abundance and food availability. Abundance of fish species considered to be potential predators of striped bass early life stages was determined by weekly deployment of a push-net at night. In addition, a continuously recording environmental station located at the lower limit of the striped bass spawning area provided data on pH, water temperature, salinity, dissolved oxygen, and rainfall every half hour from 11 March through 17 May. Juvenile striped bass were collected weekly during summer months. Survival will be determined from the birthdate distribution of the juveniles. Patterns of survival will be compared to data sets describing variations in predator and prey fields during the spawning period as well as those describing changing environmental conditions.

PROGRAM IV
DESCRIBE AND EVALUATE THE TIDAL FRESHWATER ECOSYSTEMS OF VIRGINIA'S MAJOR RIVERS.

Charles Roadley (right) and Berch Smithson set up equipment to collect water samples in the tidal freshwater wetlands net flux study.

Tidal Freshwater Wetlands. This program is designed to describe the structure and function of tidal freshwater wetlands. Work in this program has been focused for the past three years on a large marsh in the Pamunkey River, Sweet Hall Marsh. The marsh and adjacent uplands are owned by Tacoma Hunt Club, a private club which has generously permitted the Institute to use its marsh and onshore facilities to conduct the research and monitoring studies necessary for this project. The principal focus of the initial studies has been description of processes affecting nutrient cycling both in the marsh and between the marsh and adjacent river. During 1987-1988 most of the field work required for these studies has been completed with the continuing effort now primarily directed at data analysis and report preparation. The Tidal Freshwater Wetlands Program has included the following individual projects:

1. Description of the primary production of the overstory and understory in tidal freshwater swamp communities. Results of this project were presented in a thesis and published in a symposium proceedings. The information is also being used as the basis for design of a more comprehensive study of swamp community structure along the salinity and tidal gradient from Sweet Hall Marsh to the limits of tidal activity in the Pamunkey River.

2. Description of the seasonal concentration of nutrients in plants and soils of the marsh communities. Data collected in this project has been used to construct models of the seasonal standing stocks and fluxes of nutrients in the *Peltandra virginica* and *Spartina cynosuroides* communities. This work is now being prepared for publication in a report and a dissertation.

3. Analysis of groundwater movement and related nutrient movement in tidal freshwater marshes. A computer model of the near surface hydrology of an extensive tidal freshwater marsh has been developed using the information collected during the fieldwork for this project. The results are also being used to design some additional analyses of groundwater discharge into the interior surface drainage channels of the marsh. This will provide a better understanding of the water budget of these systems and enhance our understanding of the functional relationships between the marshes and main channel water column of the Pamunkey River. The data analyzed to date is being prepared for publication in two reports and a thesis.

4. Determination of the role of sedimentation processes in nutrient cycling on tidal freshwater marshes. Results of this project are currently in preparation for publication as a report and a thesis.

5. **Measurement of the net production and turnover rate of *Peltandra virginica*.** This project has been used to evaluate both the dynamics of macrophytic production in tidal freshwater wetlands for development of the system-level model described below as well as input for the seasonal nutrient flux models described above. The project results are in preparation for publication as a report and a thesis.

6. Documentation and analysis of the waterborn nutrient exchange between marsh and river. This project was initiated last year and the field sampling will continue through the next fiscal year. The data generated by this project will be used in conjunction with the preceeding projects to develop a system level model of nutrient movements in a tidal freshwater marsh.

7. Description of muskrat impacts on the marsh system. A preliminary study of the type and extent of muskrat impacts on the macrophytic vegetation community and hydrology of Sweet Hall Marsh was completed during 1987-1988. The results are being prepared for publication and also are being utilized to evaluate and design a more comprehensive analysis of macrofaunal impacts on these systems.

8. Analysis and simulation of the vegetative succession in marsh communities. This project was initiated two years ago and involves an effort to simulate the control both biological and physical factors exert on the long-term development of the marsh system. The project requires creation of an extensive data set in support of the simulation. Field sampling occupied all of the last two fiscal years. Work on this project has stimulated several smaller studies on autecology and demography of selected plants within the marsh system. Some of this work was presented at a national meeting in 1988 and is currently in preparation for publication. The project has also stimulated a detailed study of tidal dynamics in the Pamunkey River system. Work on this aspect of the project is now focused on generation of historical tidal records for the Sweet Hall Marsh site based on VIMS tide records for Gloucester Point.

9. Simulation of tidal freshwater wetland systems. This project is designed to aid in the design and direction of various smaller projects such as those discussed above. The principal objective is to synthesize the understanding of tidal freshwater wetlands and develop a computer based simulation of both seasonal and long-term system behavior which can support even larger scale modelling projects. At present the model remains a conceptual one with simulation efforts directed at submodels based on the projects described above.

Tidal Freshwater Ecosystem. This portion of the program involves an effort to understand the relationship between the different components of the tidal freshwater river drainage basin and how they cumulatively affect materials transported to the downstream estuary. During 1987-1988 a variety of data sets required by the initial conceptual design have been assembled and the design and alternative approaches have been evaluated. This process is anticipated to continue for at least one more year before actual simulations are attempted.

Graduate students Sandy Booth (left) and Willy Reay land their Jon boat at Sweet Hall Marsh.

PROGRAM V
INVESTIGATE STRUCTURE AND FUNCTION OF MESOHALINE MARSHES AND SUBMERGED AQUATIC VEGETATION.

Big cordgrass

Mesohaline Marshes. The purposes of this project are: 1) to monitor the long-term development of man-made marshes; 2) to document changes and succession in floral and faunal communities; and 3) to evaluate the effectiveness of these marshes in replacing natural ones.

During 1983 a 10 x 30 m grid system was surveyed and permanently marked in an eight-acre study on Goose Creek, a tributary of the western branch of the Elizabeth River. Each of the 108 points have been sampled annually since 1983 to determine frequency distribution of species, characterize the plant communities, and determine the elevations at each point. These studies will continue in future years until some equilibrium within the plant community is established.

Studies designed to monitor the ichthyofaunal use of Goose Creek Marsh were initiated in 1985 and continue to the present.

Additional mitigation related studies are being conducted on a marsh created by the Navy in Willoughby Bay. The effort is focused mainly on the interspecific competition between the planted saltmarsh cordgrass, *Spartina alterniflora*, and the common reed, *Phragmites australis*, which previously inhabited the site. Common reed can be an extremely aggressive competitor in these situations. This study will aid in determining the environmental conditions necessary to control its spread.

Ecological Investigations of the Principal Factors Governing Submerged Aquatic Vegetation (SAV) Survival, Growth and Productivity in the Lower Chesapeake Bay. This project, initiated in 1984, has evolved into three primary areas of interrelated research: 1) lower York River environmental monitoring coupled with transplanting studies; 2) field and experimental laboratory studies of environmental regulation and controls on eelgrass photosynthesis and growth; and 3) ecological modelling and computer simulation analysis of eelgrass photosynthesis, growth and long-term community stability.

The working hypothesis common to all three areas is that submarine light, dissolved inorganic nutrients and temperature interact as principal components to control not only the current distribution and abundance of submerged aquatic macrophytes in the lower Chesapeake Bay and its tributaries, but also limit further community development and expansion of grassbeds into currently denuded areas of the Bay. For the 1987-1988 fiscal year, the following studies within these three areas were undertaken as either continuing or new projects.

1. Lower York River Environmental Monitoring and Transplanting Program. The physical, chemical and biological characteristics of shallow water sites in the lower York River have been monitored at biweekly intervals since September 1984. Water column parameters routinely measured are salinity, temperature, photosynthetically active radiation and its attenuation with depth, dissolved inorganic nitrogen and phosphorus, chlorophyll, and total suspended solids and organic matter. These data are used to characterize areas in the lower reach of the river that historically supported dense stands of SAV which are now limited to the downstream, near-mouth regions. Our goal, through these and concurrent experimental studies, is to develop habitat quality criteria necessary for state and federal regulatory agencies to effectively manage SAV resources. A consistent pattern of reduced underwater light and increased dissolved inorganic nutrients characterize the upriver, non-vegetated sites as compared to downriver, vegetated areas. However, whether these observed differences are sufficient to limit establishment and growth of SAV in upriver areas remains problematic and is a question being addressed in controlled, laboratory mesocosm experiments.

Transplanting *Zostera marina* in various areas of the lower Chesapeake Bay has been undertaken since 1984 as a means to: 1) develop and test transplanting methods; 2) reestablish SAV in specific, non-vegetated areas; and 3) correlate environmental monitoring data with transplant growth and survival in the field. In the York River, transplant growth and survival decreases upriver, which corresponds to the increase in dissolved inorganic nutrients, higher suspended solids concentrations, and reduced underwater light. Transplant mortality at the farthest upriver site approaches 100 percent during the summer period. The greatest differences in water quality parameters between downriver and upriver sites are observed during the spring and fall growth periods. These correlative findings support the working hypothesis that underwater light and dissolved inorganic nutrients play a major role in governing both transplant success and productivity, and distribution and abundance of natural communities. These data have also provided preliminary water quality criteria for assessing habitat quality relative to SAV resource management. The data have also provided the information necessary to adequately and realistically design field and laboratory experiments to address specific causal relations for SAV growth and survival in lower Chesapeake Bay. In addition, the transplanting program has explored and developed techniques for SAV reestablishment using both whole plants and seeds that have resulted in revegetation of previously denuded areas.

Plans for this project are to continue the environmental monitoring at selected sites in the York River to enhance the current data base and allow longer term time series analysis. This will provide the information necessary to address not only seasonal, but inter-annual variability in water quality and its relation to larger scale events (i.e., rainfall, runoff, land-use). Transplanting efforts will continue to assess cost-effective methods for artifical re-establishment of SAV's as well as an experimental tool for assessing habitat quality.

2. Field and Experimental Studies of Environmental Regulation and Controls on Eelgrass Photosynthesis and Growth. This second primary research effort within the SAV program is composed of specific projects that attempt to understand and explain causal mechanisms related to eelgrass growth, productivity, and survival in habitats of the lower Chesapeake Bay and its major tributaries. Past and current projects focus on physical-chemical and biological interactions that structure the underwater plant communities and determine abundance, distribution, and community stability. Most projects include both field and laboratory components. Studies that have either been completed recently or have been started by the summer of 1988 are outlined below.

Eelgrass photographed underwater.

a. Effects of nutrient enrichment and epiphyte grazing on dynamics of epiphytes and macrophytes in a *Zostera marina* (eelgrass) community. This project, recently completed in terms of data gathering, is a combination of field and laboratory mesocosm studies. Previous data and information on other estuaries suggests that increased nutrient loads favor the development of an epiphytic community (small organisms attached to and growing on the surfaces of plant leaves) that if severe enough would eventually cause mortality of the plant and ultimately loss of the entire community. However, natural systems generally have resident populations of organisms that control excess epiphytic growth through grazing and maintain epiphyte densities below levels that are harmful to the plant. For Chesapeake Bay eelgrass com-

Betty Bieri (right) joins Charles Roadley for sampling work at Sweet Hall Marsh.

munities, the relationship between nutrient enrichment, epiphytic growth, and potential controls exerted by grazers was not known, nor were the conditions that might result in excessive epiphytic growth regardless of grazing pressure. This project, when completed, will address the conditions leading to excess epiphyte growth, the ability and range of conditions under which grazers can control epiphytic fouling, and the ecological consequences of these interactions relative to eelgrass community stability.

b. Irradiance reduction and accumulation of total nonstructural carbohydrates in the rhizome of *Zostera marina* Loisel. This project, also recently completed relative to data collection, is a laboratory mesocosm study on the effects of reduced underwater light and the ability of eelgrass to translocate and store energy reserves (total nonstructural carbohydrates) in the rhizome portion of the plant. Eelgrass, having two distinct net growth periods occurring in the spring and fall of each year, must store energy reserves during these periods to compensate for those times of the year (primarily the summer period) when plant photosynthesis is not sufficient to meet metabolic demands (a consequence of both suboptimal light and temperature conditions). Natural, well-established communities show high summer mortalities but are able, through mobilization of energy reserves, to remain viable and enter the second fall growth period. Environmental conditions during the spring that might compromise or reduce the ability of eelgrass to store adequate reserves for maintenance during the summer period would result in plant mortality and negate the formation of stable communities. These studies address the temporal pattern and effects of reduced underwater light on the storage of energy reserves and will provide information on the effects relative to eelgrass growth and survival.

c. Response and stability of eelgrass communities in Chesapeake Bay subject to variable water quality regimes: mesocosm studies. This project, a State and federally funded (NOAA-Sea Grant) effort, is a laboratory mesocosm study of the interactive effects of reduced underwater light and increased nutrient loading on eelgrass growth, epiphytic fouling, and macrophyte productivity. Transplants are used in replicated treatments to evaluate nitrogen-phosphorus enrichment and underwater light reduction that correspond to ranges in these water quality parameters observed at sites in the York River where transplant success has varied between 0 and 100 percent. This new project is intended to run for three years and the first mesocosm studies will be completed the summer of 1988. These studies will be run seasonally and correspond to the major growth and die-back periods for natural communities. The data obtained from the studies will provide quantitative information on water quality regimes that allow for eelgrass growth and long-term community survival. These data together with the projects outlined before should allow for the development of effective management criteria and strategies for SAV resources in lower Chesapeake Bay.

d. Related studies on sediment processes and nutrient dynamics. In addition to these specific projects related directly to eelgrass, sediment nutrient concentration, depth distribution of bulk sediment physical properties, and exchange capacities have been determined at shallow water sites in the York River that correspond to both transplant and environmental monitoring sites. This project in part will begin to address plant-sediment interactions and the potential for sediment-related properties and metabolic processes to influence eelgrass growth and survival in upriver, historically vegetated areas. In par-

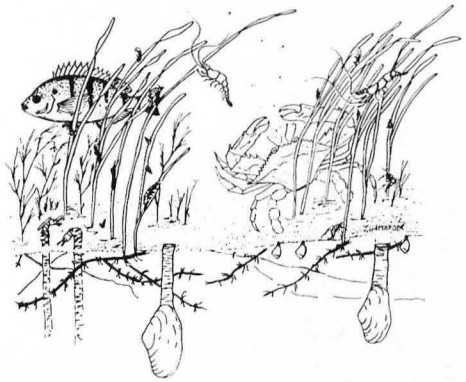
ticular, increased organic and nutrient loading to sediments (as evidenced by an upriver increase in extractable sediment ammonia and organic matter content) would favor a higher sediment microbial oxygen demand and decrease pore water oxygen tensions in and around the root zone of SAV. This potential stress, in addition to the demonstrated light stress, may further decrease plant photosynthesis and growth leading to increased plant mortality.

Continuing studies of plant-sediment relations will focus on the sources and fates of organic matter mineralization, nitrogen transformations in sediment and overlying water, and sediment oxygen distribution and dynamics at both vegetated and non-vegetated York River sites. These studies are closely coupled with more general studies of nutrient cycling in aquatic environments (see Program IX).

3. Ecological Modelling and Computer Simulation Analysis of Eelgrass Photosynthesis, Growth and Long-term Community Stability. This is a continuing effort, initiated in 1983, that evolves as new data and information are made available to guide model revision and analysis. The results of simulation analysis with the present version of the model have been used to direct much of the current research activites discussed above and to generate new hypotheses relating eelgrass growth and survival to specific environmental variables. Further revision of the model will focus on incorporating environmental monitoring data and results of mesocosm studies currently underway. The results to date suggest that the model can be applied successfully as a tool to establish criteria for resource management.

The Value of Shallow Water Habitats for Recruiting Blue Crab Populations. In comparison to marsh creek habitats, beds of submerged aquatic vegetation contained up to 90 times more juvenile crabs, indicating that these habitats are either being actively selected by recruiting crabs or recruits are experiencing greater differential mortality in marshes. The former possibility has been investigated by both laboratory and field experimentation. In both cases megalopae occurred in greater abundances in *Zostera marina* substrates than in other substrates offered (i.e., marsh mud, bare sand, live oysters, oyster shell, or artificial seagrass simulations). These results strongly suggest that megalopae are able to actively select substrates in which to settle. The current research is aimed at understanding the mechanisms whereby settling megalopae are able to discriminate between various habitats. The role of chemical ques produced by specific habitat types as a stimulus for promoting settlement under experimental conditions is presently being investigated. Such responses, if they exist, will also be examined relative to the physiological state of megalopae tested. Preliminary experiments indicated that chemical stimuli may serve as a settlement stimulus and that the settlement response could be affected by the proximity of an individual to metamorphosis.

Invoking differential predation as a cause for the observed natural distributions may be supported by the fact that the first three juvenile stage crabs are almost never present in marsh samples, and those that are occur later in the recruitment period when temperatures begin to drop and predators leave the creeks. Larger juvenile stages are found in marsh creeks, possibly indicating that some degree of refuge in larger body size has been attained by these crabs. We are currently conducting experiments on cannibalism both between and within cohorts of blue crabs and have found that juveniles around 10 mm in carapace width are not eaten by males from the previous year cohort (~150 mm), but are effectively preyed upon by smaller males (~70 mm) from the same cohort. The question of differential predation on post-larvae was examined to identify potential predators during the fall of 1987. The research found that most resident benthic fish are effective predators of megalopae. These relationships will continue to be investigated during the fall of 1988 by conducting more detailed experiments in both structured (vegetated) and unstructured (bare sand) habitats.



Eelgrass meadows provide habitats for crab megalopae, juvenile crabs and mating and molting adults. Bottom-dwelling fish and adult crabs prey on soft-shell clams and other infaunal organisms.

Our work on blue crab recruitment focuses on monitoring both daily megalopal settlement at VIMS and examining juvenile abundance in a seagrass habitat nearer the mouth of the York River. The question of spatial and temporal patterns in settlement has been addressed in a preliminary manner. A more detailed study of such processes is planned pending the availability of outside funding. Ultimately, the data from such efforts will be used to develop a population model for the blue crab.

As part of the studies on blue crabs, another area of interest is investigating aspects of habitat utilization. Part of this effort involved finding a method for permanently marking crabs. Laboratory studies which indicated that magnetic microwire tags injected into the backfin muscle can permanently mark crabs as small as 20 mm wide with virtually no effect on crab mortality. Subsequent to the laboratory experiment, a 65-day mark-recapture study was conducted on a blue crab population residing in a tidal marsh creek. Population turnover exceeded 65 days and population size increased by 1.7 percent per day, from 626 crabs at the onset of the study to 1,428 crabs on day 65. Data suggest that the population in the creek may be comprised of both a resident and a transient component. A similar study was attempted in a seagrass bed during the early summer of 1987 with inconclusive results. Population turnover within the vegetated area examined was extremely rapid (on the order of eight hours in one instance). Therefore, attempts to recapture marked individuals did not yield the number of returns necessary to conduct the mathematical calculations for the population dynamic model being used. The research team hopes to further address the issue of relative habitat value for blue crab populations by conducting mark-recapture studies in more isolated grassbeds of a smaller size than those examined to date, thereby being able to collect virtually all the crabs residing in a single patch of vegetation and examine the dynamics of the entire population.

The use of seagrass and marsh creek habitats by juvenile and adult

blue crabs as areas for molting has been examined. These studies indicate that seagrass beds contain greater numbers of crabs in late pre- and early post-molt than an adjacent marsh creek. Additionally, ecdysis occurs with some degree of lunar synchrony in the seagrass bed with the greatest percentage of molting activity occurring around full moon. The data suggest a possible directed movement of crabs towards vegetated habitats by crabs nearing ecdysis.

Investigations into the biology of blue crab populations will continue with the hope to eventually examine relationships such as factors affecting recruitment on various latitudinal scales. The development of a comprehensive program to study various aspects of blue crab ecology is underway at VIMS and such an effort will ultimately place this program in the forefront of blue crab research nationwide.

Goodwin Islands. Reasearch and monitoring efforts on the Goodwin Islands continued during 1987-1988 concentrating on the effects of fire (June 1986) on a high marsh area. Aerial photography was taken of the Islands before and after the fire providing us excellent baseline data in monitoring the affects of the burn on a long-term basis. Seasonal harvest sampling each year since 1986 has been carried on in order to better ascertain this impact that frequently happens in area wetlands either intentionally or naturally by lightening. Random one quarter meter quadrats were harvested in the burned and unburned areas of the marsh area to determine the natural recovery processes. The first year biomass study indicated that the unburned portion of the marsh increased vegetative growth four-fold over the initial production estimate in 1986. Surprisingly, the burned marsh increased nine-fold in above-ground growth during the same period. The large measure of growth in the burned area could possibly be attributed to the reduced shading caused by the burn-off and increased nutrient input of ash left after the fire. The second year study (1987-1988) indicates that the system may be reaching equilibrium because production levels in both the burned and unburned parts of the marsh are very similar. Results also suggest that the plant community structure in the former burned area is similar to the original composition. This could indicate a rapid recovery rate is taking place. Similar harvest studies will be monitored for a number of years in the future in order to document the effects of fire on a long-term basis in a mesohaline marsh.

In 1987, permanent transects were established in the marsh-forest ecotone with the intent of documenting changes in the composition of this community through time. These transects will be studied for the first time in 1988 for cover and community structure.

A plant species check-list was started in 1985 listing and documenting plants according to distinct communities found on the island complex. This was upgraded to include more species and communities in 1987-1988. This baseline data base will be very important for future studies on Goodwin Island.

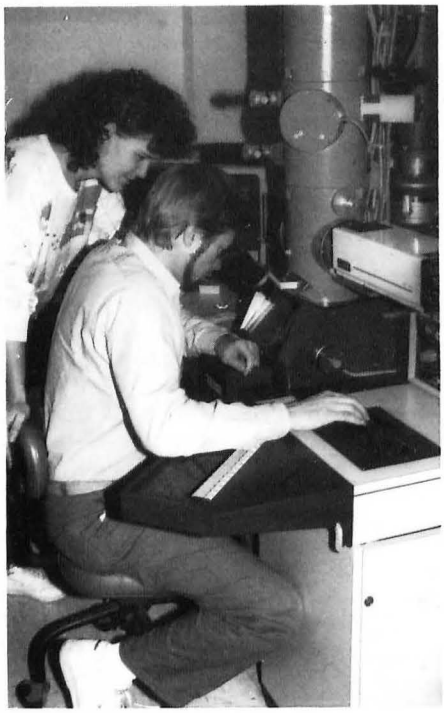
Widgeon Grass Reproductive Study. A study focusing on flowering and seed production of widgeon grass, *Ruppia maritima*, began in the spring of 1987 and continued throughout the growing season. Two sampling sites near the mouth of the York River were periodically sampled, one in a tidal, shallow, sandy bottom area at Sandy Point near the Guinea Marshes of Gloucester County and one in a non-tidal marsh pond on Goodwin Island in York County. Other sites in the York River and Mobjack Bay were sampled less frequently during the growing season. Additional collection sites were established in the Corrotoman River, a major tributary of the Rappahannock River, in October 1987. These sites are remarkable for their vegetative robustness and reproductive capacity. Individual shoots often have 4 or more flowers or fruiting stalks. Literature reports usually no more than two flowers or fruiting stalks per shoot. Some shoots were nearly one meter in length and produced more than 70 seeds per shoot. Initial collections this year have revealed that vegetative propagation is likewise incredible with more than 9000 new shoots per meter square.

Ruppia populations have recently expanded and colonized previously unvegetated shallow bottoms in certain areas of the Mid- and Lower Chesapeake Bay. The results of this study should provide a better understanding of the reproductive cycle of this important species. The study will continue in 1988 with the expansion of additional sampling sites. Preliminary data have shown that flowering begins earlier in the non-tidal ponds than in the tidal sand flats. However, as evaporation increases in the salt ponds during the summer months, plants deteriorate rapidly because of increased temperatures and salinity. Algal epiphytic growth is also much more prevalent on the vegetation in the ponds as the season progressed. *Ruppia* in the tidal habitat were much less inhibited by epiphytic algae. The data also show that *Ruppia* in our study sites become reproductive up to two months sooner than what is reported in the literature.

Core sampling of the substrate of the various sites was intiated in 1987-1988 in order to ascertain comparative nutrient composition between sites.

Goodwin Islands at the mouth of the York River.

PROGRAM VI
STUDY DISEASES OF MARINE AND ESTUARINE ORGANISMS.



Wolfgang Vogelbein is joined by Beth McGovern for work with the transmission electron microscope.

Shellfish. The life cycles of the oyster pathogens *Haplosporidium nelsoni* (MSX) and *H. costale* (SSO) continue under investigation. SSO spores were abundant again in 1987 and spore feeding experiments using possible intermediate hosts were conducted. Spore-laden oyster tissue was fed to common oyster scavengers, the mudcrabs *Panopeus herbsti* and *Neopanope texana* Sayi, and a gammarid amphipod. Examination of fecal casts with light microscopy and scanning electron microscopy revealed that spores passed through the digestive tract without opening.

The discovery of a high prevalence of *Haplosporidium* sp. from the shipworm *Teredo navalis* at Wachapreague, Virginia prompted morphological and immunological investigations of this parasite. It has been speculated that the species in shipworm is *H. nelsoni*, and that the shipworm is a reservoir host for MSX. Scanning electron microscopy of mature spores from *Teredo* revealed four epispore projections, one from the operculum opposite the hinge, two lateral, and one abopercular. Spores of *H. nelsoni* did not possess epispore projections. In addition, antibody against spores from *Teredo* did not react with spores from *H. nelsoni* in colloidal gold immunoassays. These results indicate that the haplosporidan in *Teredo navalis* is an undescribed species.

Studies are continuing to determine disease resistance of various oyster strains in Virginia waters. Broodstock are spawned in the oyster hatchery and spat are placed in an MSX endemic area and monitored for survival. Strains presently undergoing first summer testing include Delaware Bay native oysters, Delaware Bay natives five generation selected, James River natives five generation selected, Mobjack Bay native survivors, lower James River native survivors, and upper James River susceptible controls. Selected strains have been selected for survival in MSX areas, but not in areas infected with *Perkinsus marinus*, which is also abundant in Virginia portions of the Chesapeake Bay. Survival of various strains will be compared with disease susceptible controls in an attempt to develop oysters that have significantly greater survival than James River native oysters.

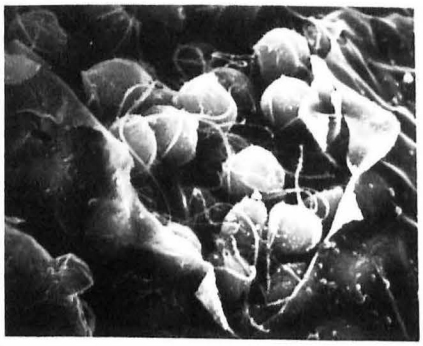
A program was initiated to develop nucleic probes for both *H. nelsoni* (MSX) and *Perkinsus marinus* for use in life cycle research, diagnosis and transmission experiments.

Effect of Environmental Factors and Parasitism on Oyster Humoral Activity (lysozyme activity). The biological roles of lysozymes in bivalves are believed to be involved with the mechanisms of host defense and digestion. Experiments were carried out to examine hemolymph lysozyme activity and protein in oysters over a one-year period to determine their relationship with seasonal environmental variables (temperature, salinity, and food availability), and whether they correlate with the parasitism of *Perkinsus marinus*. Hemolymph lysozyme and protein exhibited seasonal fluctuations relating to food availability and the oyster reproductive cycle. Hemolymph lysozyme activity varied greatly between individual oysters and it was higher in winter months than in summer months. No linkage was found between hemolymph lysozyme or protein and the infection of *P. marinus* in oysters.

Oyster Hemocyte Activities. The research project, in collaboration with Dr. William Fisher of the Horn Point Environmental Laboratory, to study the defense-related hemocyte activities and to seek whether the defense factors are related to the disease resistance of the oyster is continued. The hemocyte activities of two oyster species, *Crassostrea virginica* and *C. gigas*, have been compared. Hemocytes from *C. gigas* were found to spread and locomote faster and are more able to bind or adhere to the *P. marinus* zoospores than the hemocytes from *C. virginica*.

The effect of tributyltin (TBT, 0.4 - 400 ppb) on oyster hemocyte activities is also investigated. Chemiluminescence, a presumptive indication of phagocytic activity, was reduced with increasing TBT concentrations. Preincubation of hemocytes with high levels of TBT (40 - 400 ppb) caused great decrease of activity. A TBT concentration as high as 400 ppb totally inhibited chemiluminescence. Locomotion of hemocytes was also retarded by TBT, but the ability of the hemocytes to spread was not affected.

Acquired Immunity in Oysters. A comparison was made on the susceptibility to pathogen, *Perkinsus marinus*, between oysters which have been immunized with heat-killed *P. marinus* zoospores and non-immunized oysters. Oysters did not appear to be benefited from immunization. Immunized oysters showed similar incidence and intensity of *P. marinus* infection as nonimmunized oysters. The study has been hampered due to the difficulty of obtaining enough *P. marinus* zoospores for immunization of oysters. Interest remained high to induce acquired resistance to the oyster parasite *P. marinus* in oysters by immunization. We hope to be able to increase the dosage of *P. marinus* zoospores for oyster immunization. The current injected dosage (0.7×10^9 zoospores/oyster) may not be sufficient to generate (stimulate) response in oysters.



A scanning electron micrograph shows an undescribed species of haplosporidan found in Teredo navalis.

PROGRAM VII
DEVELOP AND PERFECT METHODS AND TECHNIQUES FOR ECONOMICAL CULTURE OF MARINE AND ESTUARINE ORGANISMS.

Oyster Culture. In a continuing effort to ameliorate the chronic shortage of oyster spat, experimental remote setting of oysters continues. The hatchery with existing tankage produces approximately 300 million eyed larvae annually. Depending on the quality of the water and cultch, setting rates of 14 to 48 percent have been achieved.

The west coast oyster industry has successfully used hatchery-reared Japanese oysters *Crassostrea gigas* in lieu of natural set for over a decade. The technique of remote setting is commonly used with setting rates of about 15 to 20 percent. Due to the excellent local environment and the fact that they are using a fast growing Japanese oyster *C. gigas* instead of *C. virginica*, the remote set oysters need only be held intertidally for an initial growth and hardening period before they are moved to their final oyster beds or floats where they are grown to market size.

Collaborative experiments with a number of entrepreneurs have shown that an intermediate nursery phase is necessary to ensure a good survival of post set *C. virginica* oyster spat. The spat needs protection until it reaches a sanctuary size of about one inch in length. A series of experiments on nursery systems are presently being tested, including upwelling tanks, tray and trestle system, and pallet-type trays. As part of this study, methods of handling cultchless (or mini cultch) oysters are being developed. This technique greatly reduces the amount of shell stock needed for cultch and reduces handling and transport problems. Cultchless oysters are more vulnerable to predation and smothering than oysters set on larger shell and may require good hard growing bottom, prepared beds, or an off-bottom grow out system.

Information on remote setting and nursery techniques is being disseminated to the growers through bulletins and direct contact. So far this year about 70 million eyed larvae have been furnished to five entrepreneurs for collaborative experiments.

Hard Clam Farming. The Wachapreague Laboratory continues its commitment to the development of *Mercenaria mercenaria* culture. A short course on farming clams was again offered this spring. The participants came from four states. Over 190 have taken the course since it started. In addition to those who have taken the course, over ten interested entrepreneurs have visited the facility.

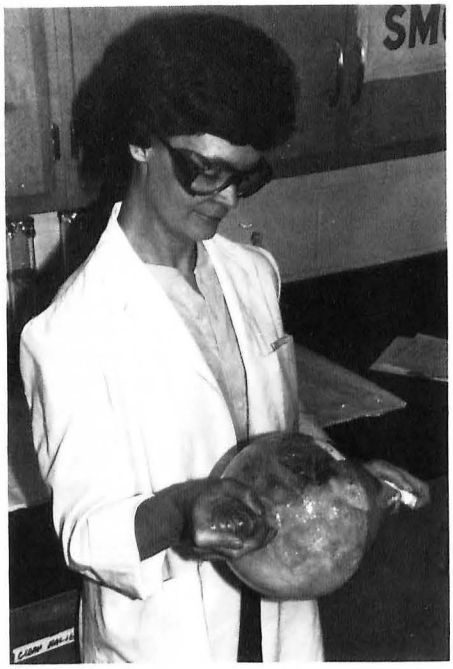
Pilot-scale production of clams continues for experimental and demonstration purposes. In addition, several lines of clams selected for superior growth are being grown for spawning stock.

Metabolism of Dietary Fatty Acids in Oysters. This program was initiated in 1985 and supported by the National Science Foundation. During fiscal year 1987-88 efforts have been made to investigate the effects of temperature on the process of elongation of dietary fatty acids (palmitic (C16:0), linoleic (C18:2ω6), linolenic (C18:ω3) acids). Temperature effect on the incorporation of these fatty acids (^{14}C-labeled) into neutral and polar lipids are also examined. Percentage of ^{14}C-18:2ω6 fatty acid elongated to longer carbon chains (i.e., 20:2ω6 and 22:2ω6) were greater at 20°C than at 5°C. This is also true for linolenic acid (C18:3ω3). At both 5 and 20°C, elongation of palmitic acid to longer chain (e.g., 18:0) was <1%. Change of water temperature did not seem to affect the amounts of ^{14}C-18:2ω6, ^{14}C-18:3ω3 to incorporate into the oyster lipids. In most of the oysters (11 of the 15 tested oysters), incorporation of these two fatty acids (percentage of isotope incorporated to neutral or polar lipid) into polar lipids was higher than neutral lipids. In contrast, palmitic acid incorporation into neutral lipids exceeded that into polar lipids; at 20°C, the incorporation of C16:0 was reduced.

In addition to these studies, seasonal changes in anatomical distribution of the lipids and fatty acids in oysters have been determined. The changes found in the lipids of the visceral mass were related to the sexual cycle of the mollusks. Seasonal variations of eicosapentaenoic (C20:5ω3) and docosahexaenoic (C22:6ω3) acids were small. These two fatty acids which are considered to be essential for oyster growth, are beneficial to human health. The oyster is able to regulate or maintain major fatty acid constituents for a short term, particularly the polyunsaturated fatty acids (PUFA) in its tissue in a relatively constant proportion, regardless of the fluctuation of lipid content and PUFA in the diet.

Oyster hatchery manager, Ken Kurkowski, transfers oyster larvae to a larger tank.

PROGRAM VIII
DETERMINE THE FATE AND EFFECTS OF TOXIC CHEMICALS IN THE CHESAPEAKE BAY SYSTEM.



Donna Westbrook agitates a separatory funnel for liquid—liquid extraction as part of the tributyltin analysis process.

Polynuclear Aromatic Hydrocarbons (PAH).

PAH Metabolites. It is known that the Chesapeake Bay environment contains many hundreds of anthropogenic organic chemicals. The concentrations of these chemicals are rarely high enough to cause acutely toxic effects. However, they may cause chronic changes in the biota of the Bay that are difficult to detect. Polynuclear aromatic hydrocarbons (PAH) are a group of chemicals that fit this category. These compounds are commonly synthesized when organic matter is subject to incomplete combustion, e.g., in the internal combustion engine, the burning of wood and fossil fuels, and the smoking of tobacco. While some PAH have been found to be mild mutagens and/or carcinogens, they may become powerful mutagens and/or carcinogens after they have been metabolized. It is therefore important to thoroughly understand the metabolism of these compounds, with the aim of correlating specific features of the metabolic process with observed pathological changes.

High performance liquid chromatography (HPLC), a technique for separating complex mixtures, has been used to look at samples from fish that have been environmentally contaminated with mixtures of PAH, fish that have been treated with individual PAH, and control samples. The results showed that fish from the Elizabeth River contained large numbers of compounds that had the fluoresce fingerprint of PAH metabolites and that the number of these compounds was larger, and the concentrations higher, than in fish obtained from the much cleaner Nansemond and York rivers. The results from the injection of fish with individual PAH also indicated the presence of metabolites in the bile. It was not possible to correlate the two types of samples and therefore a method for identifying individual peaks is being developed. This method is combined high performance liquid chromatography- mass spectrometry using a thermospray interface. This interface has proved to require much skill for its successful use. In addition the compounds being investigated, metabolites of benzo(a)pyrene, appear to be extremely thermolabile, especially those conjugated with glucuronic acid and sulfate moieties. The compound specificity of the thermospray interface and the lability of conjugated metabolites makes the latter especially difficult to analyze. While not ideal, the information being generated is relevant and important and will provide complementary information to HPLC. Once the methodology to concentrate the compounds has been developed, it will allow us to determine the general identity of PAH metabolites.

Contaminants in the Surface Microlayer. The sea surface microlayer of the Chesapeake Bay is a vital habitat for transport and feeding of many commercially important species such as oysters and blue crabs. Natural and anthropogenic materials from both subsurface aquatic and atmospheric sources concentrate at the air-water interface, or the sea surface microlayer. High levels of potentially toxic polynuclear aromatic hydrocarbons, chlorinated organics and metals have been found in the microlayer of coastal areas. The objective of this project, conducted over the last year in cooperation with the State Water Control Board, was to develop a suitable sampler to determine levels of certain pollutants in the microlayer.

A reliable surface microlayer drum sampler was developed and an extensive sampling program conducted in the York River system. In 16 cruises, over 50 percent of the surface microlayer samples were shown to be enriched with polynuclear aromatic hydrocarbons (PAH). Enrichment factors for both total PAH and tributyltin ranged from 5 to 200, i.e., relative to the underlying water column concentrations.

Concentrations of total PAH in the York River ranged from 0 to 7 µg/L, in the Pamunkey River from 5 to 47 µg/L and in Sarah Creek from 0 to 135 µg/L. The principal compounds detected in the surface microlayer were C-2 phenanthrene, fluoranthene, methylphenanthrenes, methylphenylnaphthalene and phenanthrene. The composition of the microlayer samples was similar between stations and seasons. Based on published toxicity data, the concentrations of PAH in the York River system microlayer do not appear to present a hazard to biota. However, the concentrations of tributyltin were quite high in the microlayer samples, indicating potential toxicity problems, especially for bivalve larvae.

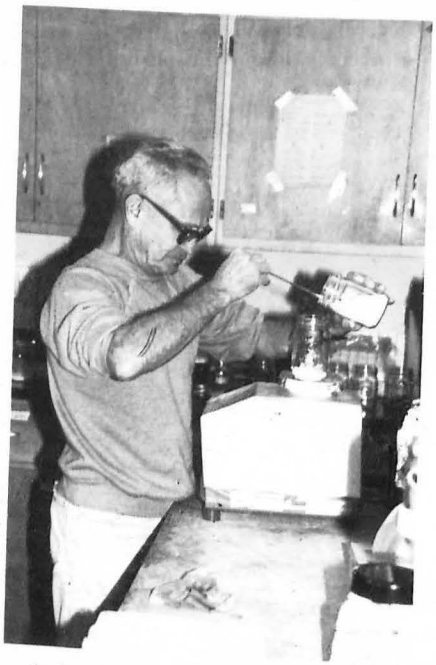
Effect of Sunlight on PAH Toxicity to Fish. In PAH-exposure experiments at VIMS, cataracts have been found in fish in one group, but not in others. One major difference among the various groups was the presence or absence of sunlight. Since sunlight has been shown in other studies to increase the acute toxicity of specific PAH to fish, a preliminary experiment was designed to test the effects of sunlight exposure on the toxicity of PAH-labeled sediments. Fish were exposed to both contaminated and non-contaminated sediments in the absence of sunlight, after exposure of the sediments to the sun, and in direct sunlight. No gross effects such as body lesions, fin erosion, dose-related mortality or cataracts were observed. Eyes were preserved for future histological examination for cataract precursor conditions when appropriate equipment and personnel become available. While the doses were low and perhaps below the threshold for overt cataract formation, superoxide dismutase (SOD) activity in the eyes was affected at the doses tested. All fish exposed to PAH-contaminated sediment had significantly lower ocular SOD than those exposed to control sediment. There was also a trend for increasing ocular SOD based on degree of sunlight exposure. A PAH effect was also demonstrated by the presence of PAH metabolites in bile samples of exposed fish indicating that the fish did take up PAH.

Further diagnoses of possible chronic toxic effects are underway and additional experiments to examine the relationship of PAH and sunlight to eye diseases noted in earlier field and laboratory observations are planned.

Mixed Function Oxygenases. The long-term purpose of this project is to evaluate the possible confounding effects of environmental parameters on the use of mixed function oxygenases in the finfish, spot, *Leiostomus xanthurus*, as an early indicator of pollution. During the past year, various assays planned for use in this project have been carefully tested before engaging in the study of temperature and salinity effects on mixed function oxygenases. In addition to the aryl hydrocarbon hydroxylase (AHH) assay, the EROD assay has been implemented as well. The variance for each assay which can be expected in repeated assays is now available so that one can calculate the appropriate sample size needed to detect significant differences in response to various treatments. Examination of the effects of environmental variables will begin in late 1988 or early 1989.

Toxicology and Pathobiology

Acute Toxicity of Tributyltin to Oyster Larvae. The ongoing series of flow-through tests with oyster larvae were terminated early in this fiscal year. It was concluded that while the mini test table system designed specifically for small invertebrate tests functioned reliably, survivorship of oyster larvae in control water did not meet the criterion level for an acceptable toxicity test.



A tissue sample is weighed by Harold Slone prior to analysis.

Despite the low control survival, several LC50 estimates were made which were closely similar to LC50 values previously obtained in a static renewal oyster embryo test. While growth of control larvae was much less than one would expect based on hatchery (static renewal) culture, nevertheless it was markedly greater than that observed for larvae exposed to tributyltin (TBT). TBT-exposed larvae exhibited virtually no growth even at concentrations of 0.2 µg/L.

Bioconcentration of Tributyltin by Adult Oysters. During this fiscal year, an oyster bioconcentration test was performed to compare uptake of sediment-associated TBT with uptake of dissolved TBT. The latter treatment was a repeat in part of the uptake study completed during the preceding year. In addition we attempted to measure the uptake and clearance of dibutyltin (DBT), the initial decomposition product of TBT, in water and associated with sediment.

The uptake rate of TBT from solution observed in this study was nearly identical to that measured previously. Similarly, the clearance rates were nearly identical. The result is that the bioconcentration factors calculated for each of the experiments differed by a factor of only 1.6 (9240 in 1986-87 vs. 5910 during 1987-88). In addition, the uptake rate of sediment-associated TBT was not significantly different from that of dissolved TBT; therefore, the bioconcentration factor was also the same (5910 for TBT in solution vs. 5740 for TBT in sediment). Presumably this reflects the great tendency of TBT to enter solution when contaminated sediment is resuspended, resulting in the same bioavailability of the TBT. A publication describing these results is in preparation.

In the parallel DBT uptake tests, sediment-accommodated DBT exposure concentrations were not sufficiently constant to allow interpretation of the data. It is thought that this non-constancy of the exposure concentration resulted from inadequate mixing of the highly viscous DBT with the sediment in the stock preparation. Tissue analyses have not, however, been completed for this experiment since it is unlikely that the data could be meaningfully interpreted; tissues have been archived for future analysis.

A Survey of Potential Problems Related to Toxic Organic Chemical Contamination of Aquatic Environment.

Toxicity of Natural Waters to Bivalve Larvae. Four surveys of selected stations were completed involving a total of 20 stations in the Virginia portion of the Chesapeake Bay. When tested with oyster embryos, water from several sites was found to have toxic effects at some times and not others. For example, a York River sample taken near West Point, Virginia, in December was found to be toxic, but subsequent samples were not. Similarly, samples from stations in the Elizabeth River were usually nontoxic, but during one cruise (March 1988) both surface and bottom water samples from Station 217 were found to be toxic. This occurred during a period when considerable sediment was suspended in the water. The type of response differed, however, from that obtained with an elutriate of sediment collected from the same station. One other instance of toxicity was observed at a station near the Lynnhaven Inlet. While not statistically significant, mortality was greater than in the control and was lessened by dilution of the natural water with reference water. Thus the test appears to be sensitive to toxicity in a natural water mass.

Attempts at evaluating the class of chemical causing toxicity by chemical fractionation using the Walsh and Garnas (1983) method were not successful. Reference water samples, fractionated according to the protocol, showed toxicity resulting from the fractionation procedure itself. Since efforts to alleviate this problem have to date not provided fully interpretable data, an alternative fractionation scheme is being sought.

As part of the project, a manual was prepared documenting in detail all methods used in this procedure. Prior to cessation of external funding for this project, a week-long training session was held for personnel of the Virginia Water Control Board.

Immunotoxicology. The objectives of this program have been to develop sensitive and reproducible assays of the cellular immune activity of fish to be used as measures of the biological effects of exposure to toxicants and the overall health of fish.

It has been observed that certain phenomena of the cellular immune system of fish, such as cell migration, chemiluminescence, ingestion and killing of bacteria by macrophages,

etc., can be related to challenges due to environmental stress. In studies of estuarine fish, including spot, hogchoker and toadfish, it has been shown in this laboratory that macrophages extracted from fish exposed to the various complex contaminants in the Elizabeth River are less able to migrate, chemiluminesce, ingest and kill bacteria than those from fish captured in the cleaner York River, or from other reference systems in the lower Chesapeake Bay. These findings have been verified by controlled exposures of the same species to the same sediment-related toxicants in the laboratory.

In addition, the effects of exposure to the antifouling agent tributyltin (TBT) on the fish cellular immune system has been under study in this laboratory. Both phagocytic uptake of foreign particles and chemiluminescence are enhanced by exposure to TBT levels of up to 500 parts per billion. At higher TBT levels activity is suppressed. Since enhancement is dependent on the availability of calcium ions to the macrophage, it is concluded that TBT affects macrophage activation by influencing membrane integrity and affecting calcium mobilization. It is anticipated that these studies will help to elucidate the mechanism of cellular toxicity of TBT.

Work is continuing on these and other studies investigating the immune system of marine organisms. In future studies, these assays will serve as biomarkers of aquatic pollutants and their effects on the health of estuarine fish.

Pathobiology. The objectives of the pathology research program at VIMS include the following: 1) investigate reports of diseases and fish kills in feral populations; 2) determine causes where possible; 3) acquire important facts relative to the effects of toxicants and other contaminants on the health of individual finfish and their populations in Virginia's tidal waters; and 4) determine implications for environmental and human health.

Reports of diseased fish and fish kills from the lower Chesapeake Bay region have been investigated in fiscal year 1987-1988, i.e., the spring menhaden kill of 1988 off bayside of the Eastern Shore and the baywide bluefish kill. However, the major focus of this research has been on continuing studies of the effects of contaminants in the sediments on migratory and resident species of finfishes in the Elizabeth River. Comparison collections have come from the less-contaminated nearby Nansemond River and sites in the more-distant York River and Mobjack Bay. These studies have been coordinated with those of the immunology research group and samples of bile have been provided to the chemistry unit for microchemical analyses.

Grey trout with cataracts.

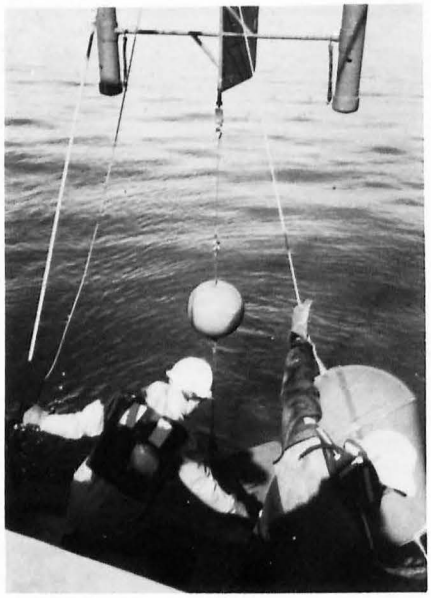
From an extensive sampling effort, involving over 80,000 finfishes of several species, a number of disease responses have been recognized which are clearly related to those sites in the Elizabeth River whose sediments are most heavily contaminated, especially by PAH. Among them are externally-visible lesions such as hyperemia, fin rot, ulcerations and cataracts of the eye lenses. Nansemond River fishes have been essentially free of such lesions. Continuing studies involve statistical analyses of disease prevalence in all collections from 1982-1986 by species and by sites. Research to determine if these external lesions can be used as early-warning signs for bioassay and monitoring of environmental toxics also continued.

Ecological studies and histological examinations have concentrated on gills, liver and kidneys, all of which are important in intake, transport and processing of contaminants and metabolites. Impacts on tissues of eyes have been observed and reported. This work continues to focus upon five "offshore" fishes: hogchoker and oyster toadfish, both endemic benthic species, spot and Atlantic croaker, both migratory, pelagic bottom-feeding species, and weakfish, a pelagic predator. Numerous skin, gill, kidney and liver lesions have been found, many related directly and positively to the most severely contaminated site in the Elizabeth, VIMS station 7 (stations identified earlier as 218 and 217). In addition, preneoplastic and neoplastic lesions are in some organs of several of these species.

In 1987-1988 the mummichog, *Fundulus heteroclitus*, an inshore, shallow-water species, was added to the sampling program after discovery of a tumor in the lips and mouth. Subsequent study of 882 individuals revealed eight (ca. 1.0%) bore non-neoplastic lesions associated tentatively with trauma and environmental stress and eight (ca. 1.0%) had tumorous growths which may be associated with environmental stress. Of the second group of eight tumors, six were diagnosed as incipient and frank oval epidermal papillomas, one was a capillary hemangioendothelioma of the gill chamber with gill complications and one a schwannoma of the pectoral fin. All eight came from station 7 in the Elizabeth River, but no firm connection to sediment-contained PAH has been made at this point, due to lack of reference collections for comparison. This aspect remains to be examined further. However, the presence of these neoplasms is extremely interesting.

Much has been learned from the field and laboratory studies of effects of Elizabeth River contaminants to date and a number of scientific communications have resulted. A considerable amount of work remains to be done.

PROGRAM IX
STUDY NUTRIENT CYCLING PROCESSES AND CONTROLS IN RIVERINE, ESTUARINE AND COASTAL MARINE ENVIRONMENTS.



A particle interceptor trap is employed as part of efforts to better understand the timing and rate at which organic materials settle out of the water column and onto the bottom.

Is Phosphorus Removal An Efficient/Effective Chesapeake Bay Management Practice? This project completed its second year to determine which nutrient, nitrogen (N) or phosphorus (P), limits or controls phytoplankton primary production on a seasonal basis in the lower Chesapeake Bay. Managers generally agree that: 1) nutrient enrichment is a major cause for water quality degradation of the Chesapeake Bay and its tributaries; 2) reduction of inputs of nitrogen or phosphorus, or both, will be necessary to improve Bay water quality; and 3) a phosphate detergent ban is a significant interim step toward reducing nutrient inputs to the Bay.

Nutrient enrichment is thought to promote the deterioration of receiving waters by stimulating algal growth. Excessive algal biomass contributes, through its subsequent death and decomposition, to low oxygen concentrations in deeper waters. The paradigm that algal production is typically phosphorus-limited in fresh waters and nitrogen-limited in marine waters does not take into account estuaries where one might assume that some intermediate or non-steady state conditions should exist. The present study, together with a similar project carried out at lower salinities by colleagues in Maryland, seeks to develop an understanding of the temporal and spatial extent to which a given nutrient limits or controls algal production in Chesapeake Bay.

Using the combined data sets, the picture has emerged that nitrogen controls phytoplankton production in the estuary during the warmer months, from late in the spring bloom period until fall, over a wide salinity region, i.e., from nearly oceanic salinity into the tidal freshwater reaches of the estuary. The remainder of the year phosphorus controls the primary production. The data correlate well with temperature and not with salinity, reinforcing the seasonal interpretation. The underlying mechanisms of alternating phosphorus and nitrogen controls on phytoplankton production appear to be related to the nutrient loadings of the system. Major nitrogen loading is in the winter time with freshwater run-off carrying nitrate from the terrestrial system into the estuary. Nitrogen supply greatly exceeds phosphorus supply and phosphorus is limiting in the winter. In the warmer months, freshwater inputs are much reduced but there is increased release of phosphorus from the sediments; the phosphorus supply exceeds that of nitrogen and nitrogen is limiting in summer.

The present working hypothesis suggests that the change-over from phosphorus to nitrogen control of the phytoplankton production occurs during the latter stages of the spring bloom of phytoplankton. The production of that bloom undoubtedly is not utilized at that time, but carries over to summer and fuels the oxygen utilization in bottom waters which results in anoxia problems. Although phosphorus supply appears to control the daily intensity of the spring bloom, its duration is controlled by the total nitrogen input to the system in winter.

The optimal nutrient control strategy will have to take into account nitrogen loadings as well as phosphorus loadings. The scenario presented above indicates that controlling nitrogen loading from fresh water across the fall line is an important factor in controlling the production which results in anoxic conditions in the deeper Bay waters in the summer.

Nitrogen Cycling Processes and Controls for the Chesapeake Bay and its Major Tributaries. This program, first planned in 1984 but not fully implemented until 1987, is composed of several specific projects (outlined below) that center on nitrogen cycling in estuarine environments. Nitrogen was decided as the nutrient of interest because it is an essential element for plant and animal nutrition and is considered a limiting nutrient for primary production in estuarine and coastal marine ecosystems. In cases of excess loading, nitrogen enrichment of coastal aquatic environments leads to deleterious effects. The current paradigm suggests that excess nitrogen loading results in excess aquatic primary production, increased vertical flux of organic matter and nutrients to the benthos, alterations in planktonic and benthic food webs, and a generalized deterioration in water quality (e.g., hypoxic and anoxic waters, elevated biological oxygen demand, increased water column turbidity).

The overall goal of this program is to understand the spatial and temporal dynamics of nitrogen in the lower Chesapeake Bay and its tributaries and in particular to identify and quantify those processes that control nitrogen cycling in both natural and impacted habitats. A specific objective is to understand the relationships between external nitrogen loading and internal processing, and living resources of the receiving water body. To these ends, the following projects were undertaken during fiscal year 1987-1988 as either continuing or new studies. For most studies, the geographical area of focus has been the York River estuary and its trubutaries although expanded coverage of the lower Chesapeake Bay is planned for future efforts. Within this program, a significant effort has been devoted to the development and testing of new or improved techniques for investigating nitrogen dynamics in aquatic environments and should lead to better and more precise understanding of the dynamics of this important nutrient element.

Nitrification and Ammonia Remineralization in Waters and Sediments of the York River Estuary. This project, initiated in 1987, investigates two principal components of the nitrogen cycle that are mediated by naturally occurring bacteria populations. Nitrification, the oxidation of ammonia to nitrate, accounts for nitrogenous oxygen

demand and provides the substrate (nitrate) for denitrification (i.e., the reduction of nitrate to nitrous oxide and nitrogen gas). Ammonia remineralization is the principal recycling mechanism for nitrogen and accounts in many instances for the bulk of nitrogen required for autotrophic production.

Preliminary studies (summer and fall 1987) of sediment nitrification were undertaken at six shallow water sites in the York River. The study sites were located near the river mouth and extended upriver to its head at the confluence of the Mattaponi and Pamunkey rivers. These initial studies indicated that nitrification rate in sediments increased downriver and was inversely correlated with sediment organic matter and positively correlated with water temperature. Based on these results, three sites were chosen along the river axis for longer term studies and to reflect environmental gradients in sediment type, salinity and ambient dissolved inorganic nutrient concentrations. The sites are located in the vicinity of VIMS, Clay Bank and the Poropotank River mouth. Beginning in March 1988, sediment and water column nitrification, and water column ammonia remineralization have been measured at monthly intervals.

These studies when completed and the data analyzed will provide quantitative estimates of two important processes involved in nitrogen cycling and provide correlative indices of environmental factors controlling these rates. The data will be particularly valuable in addressing water quality modelling issues and provide better understanding of nitrogen cycling in various estuarine environments.

Sediment Oxygen Demand and Nutrient Exchange in Shallow and Deep Water Sediments of the York River Estuary. This project is a companion study to the nitrification and ammonia remineralization studies discussed above. Sediment oxygen consumption results in the depletion of oxygen in overlying waters with the concomitant release of nutrients (primarily ammonia). In shallow waters, oxygen is replaced by ***in situ***, microalgae production, advection of water and atmospheric re-aeration. In deeper waters, vertical mixing of oxygenated surface waters supplies oxygen to bottom waters. Oxygen concentration within sediments influences many biogeochemical processes and controls, at least in part, benthic community composition. Hypoxic and anoxic waters are the result to large extent of sediment oxygen demand exceeding processes that re-oxygenate the water column.

These studies are designed to describe the temporal and spatial patterns of sediment oxygen consumption and nutrient exchange with overlying waters in both shallow and deep areas of the York River and a mid-Chesapeake Bay study site. Studies were initiated in late winter 1987 at the VIMS, Clay Bank and Poropotank River mouth sites chosen for nitrification and ammonia remineralization studies. Deep water sites will be added to the program in fall 1988.

The data generated from these studies will provide direct measurements of sediment oxygen demand and nutrient regeneration for a variety of sediment types located along environmental gradients of salinity, suspended solids concentrations and ambient nutrient concentrations. The data will also be made available for calibration and verification of water quality models.

Vertical Flux and Composition of Suspended Particles in the Lower Chesapeake Bay: Sediment Trap Studies. In shallow water estuaries, sediment related processes influence and in many cases control overlying water quality (nutrient concentrations and dissolved oxygen concentration), the decomposition of organic matter, and the regeneration of nutrients. The U.S. EPA (Chesapeake Bay Program) has incorporated as a principal component in the 3-D water quality model for the Bay the sediment related processes of organic matter decomposition, nutrient regeneration and longer term sediment diagenesis. These processes are driven largely (hypothetically) by the vertical flux of suspended particles to the bottom. The studies undertaken in this project are designed to provide the data necessary to implement the sediment processes model.

Employing a vertical array of particle interceptor traps at the mouth of the York River and at a station located approximately mid-way across the lower Chesapeake Bay, the vertical flux of suspended particles has been determined at either weekly or biweekly intervals (depending on season) since April 1988. The project is planned to run for one year from its initiation and is an interdisciplinary effort between the divisions of Biological and Physical Oceanography at VIMS. The flux measurements will be reported in terms of elemental composition (i.e., carbon, nitrogen, phosphorus and silica), bulk properties (total organic and inorganic mass) and general characterization of organisms involved.

These studies will provide the first direct measurements of the flux of materials to the bottom that provide the substrates for microbial decomposition and nutrient regeneration which results in sediment oxygen demand and bottom water oxygen depletion. These studies have direct bearing on the current problem of hypoxia and anoxia in Chesapeake Bay waters.

Isotopic Determination of Nitrogen Sources and Processing in Chesapeake Bay and its Tributaries. This is a continuing project (initiated in January 1984) with funds provided by various state and federal programs; NOAA-Sea Grant, Cooperative State Agency Program, and Commonwealth of Virginia. It is a collaborative effort and involves scientists at VIMS and the University of Virginia. At various times, the project has involved scientists outside the Virginia system and has included researchers from the universities of Maryland, North Carolina, and Georgia. Interactions with institutions other than the University of Virginia have been in the area of techniques development.

Peter Eldridge works on the uptake and release of nutrients in phytoplankton and bacteria.

The stable isotope of nitrogen (N-15) can be used as both a natural tracer and experimental tracer in studies of nitrogen cycling and specific microbially mediated processes. The natural abundance of N-15 (expressed as a ratio relative to N-14) varies as a function of nutrient source and isotopic fractionation due to biochemical processing. N-15 enriched compounds (i.e., NO3 and

NH4) are commerically available and can be used as specific tracers of nitrogen transformation processes just as radioisotopes have been employed for several decades. Although long employed by soils scientists in agricultural research, experimental use of the N-15 isotope in nitrogen cycling studies in the marine sciences is recent.

Studies within this project can be divided generally into: 1) surveys to describe the natural abundances and isotopic compositions of selected water, sediment, and biological samples; and 2) studies using N-15 enriched compounds as an experimental tracer. For the first area, surveys for N-15 natural abundance are continuing at selected sites in the York River, James River and lower Chesapeake Bay with the objective of identifying specific nitrogen sources based on unique isotopic ratios. For the second area, reliable techniques for the use of N-15 tracers in studies of water column nitrification and ammonification (ammonia remineralization) have been developed. For both study areas, sites have been selected that reflect natural environmental gradients and specific land-use characteristics (agricultural, rural development, sewage impacted and natural).

N-15 nitrification studies in the upper James River were completed during this fiscal year. For the first time, direct measurements of water column nitrification as a function of downstream distance from sewage treatment plants (STP), river flow, and temperature were made. The data indicate that nitrification occurs at significant rates below STP's (particularly during low flow conditions) and contributes to low dissolved oxygen concentrations in the river. Prior to these direct measurements, nitrification was only suspected as important relative to downstream water quality and data used for water quality modelling had no verifiable data base.

The analytical methods and protocols developed in the program to date have found application as a powerful research tool in resolving not only specific questions regarding nitrogen processing, but providing data and information necessary for development and application of water quality models intended for resource management. Continuing studies will broaden the data base on rates of nitrogen cycling and lead to better understanding of the role of nitrogen in riverine, estuarine and coastal marine ecosystems.

PROGRAM X
EVALUATE FACTORS LEADING TO, AND THE CONSEQUENCES OF NUTRIENT ENRICHMENT.

Sediment cores, like the one held by Sam Wilson, are collected to determine the amount of organic material in the surface sediments.

Sediment-water Column Exchanges. For years scientists have known that remineralization processes in estuarine sediments release nutrients to the overlying waters. Water quality modellers are now including this factor in their models. In order to maintain mass balance it is necessary to know the flows in both directions. Moored arrays of particle interceptor traps have been placed in the lower York River and in lower Chesapeake Bay. Duplicate traps, positioned at three depths, provide information on the rate at which particulate materials (and the nutrients contained in those materials) settle out of the water column.

These monitoring data will be used in the water quality modelling studies being conducted by the United States Army Corps of Engineers as part of the Chesapeake Bay program. In addition, scientists will use the information to improve their understanding of planktonic processes related to nutrient enrichment. In particular, some believe that elevated nutrient concentrations favor the production of very small phytoplankton (e.g., cyanobacteria), which may be expected to sink out of the water column to a far lesser degree than larger phytoplankters (e.g., diatoms). The monitoring includes microscopic and chemical characterization of both the materials suspended in the water column as well as in the traps. Thus, the degree to which the size distribution of phytoplankton influences the rate of particle sinking will be discerned. Monitoring of the Chesapeake Bay trap array will continue through the spring of 1989, whereas monitoring of the York River traps will cease in early winter of 1988-1989.

PROGRAM XI
UNDERSTAND THE DYNAMICS OF BENTHIC BOUNDARY LAYERS AND ASSOCIATED PROCESSES OF SEDIMENT RESUSPENSION, TRANSPORT AND ANIMAL-SEDIMENT INTERACTION IN COASTAL AND ESTUARINE ENVIRONMENTS.

The overall objective of this program is to determine the dynamics of the benthic boundary layer with respect to sediment resuspension and transport. The underlying goals are to improve management of dredged materials, predict and control shoaling in navigable waterways and ports, predict the accumulation or erosion of different types of sediment, and anticipate and avoid possible buildup of toxics adsorbed to certain types of sediment. Research efforts addressing these objectives were pursued vigorously in FY 1987-1988. In the past two annual reports technological advances in measurement tools for investigating sea floor and bay floor phenomena and the application of those tools in the study of the dynamics of different bottom types were reported. In the past year, additional, innovative field technologies were developed for studying fine-grained (mud) beds, the field data base was appreciably expanded, and new field-supported computer models for predicting sediment transport were developed.

In the way of research technological developments, an annular flume capable of experimentally determining the critical shear stresses at which sediment is entrained from natural beds was designed and computer modelling was completed to evaluate the flume characteristics. The flume, which is now under construction, will be deployed from a research vessel on natural beds in the Chesapeake Bay. In addition, the benthic boundary layer tripods are being significantly upgraded to incorporate other "muddy-bottom" dynamics sensors that were designed over the past year. Notably, VIMS researchers have designed sensor packages which can be imbedded in soft, mud beds and can provide data on the motion, shear-strength, and pore-water pressures of the muddy substrate.

Numerous field experiments involving deployments of the benthic boundary layer tripods were conducted in fiscal year 1987-1988. A field experiment conducted at the

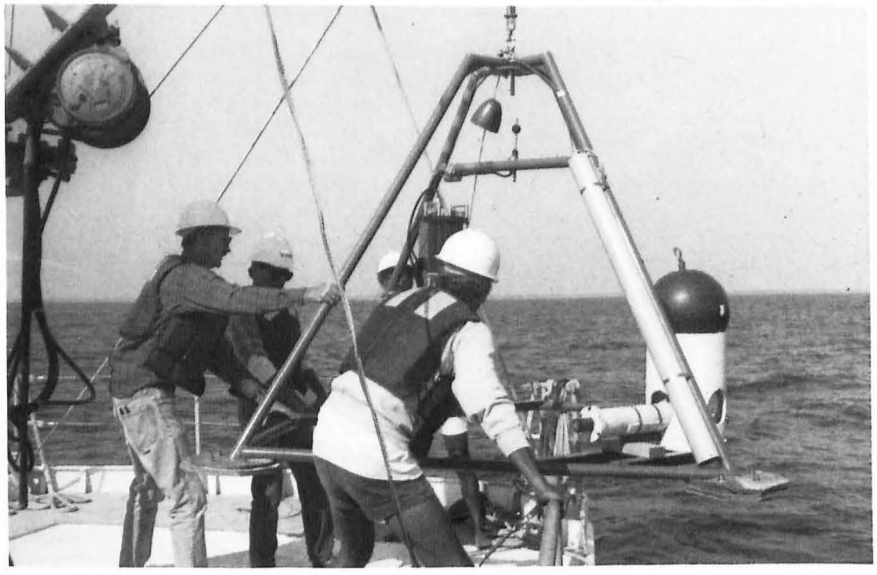
Wolftrap site in the Bay's mainstem region focused on acquiring additional details of the sediment-transporting processes operating in this region, and, particularly, the roles of high frequency internal waves and "bursting" phenomena (shear stress fluctuations with periods of about 100 seconds). Field experiments were also conducted over the Duck, North Carolina shoreface in summer (July 1987) and winter (January 1988). Side-scan sonar surveys were run at the start and finish of each experiment. In addition, a series of images of the bed from the 18 m depth contour to the 5 m depth contour were obtained using the VIMS sediment profiling camera at the start and finish of the summer experiment and at the finish of the winter experiment. The summer experiment was concerned with documenting the processes which cause fair-weather cross-shelf transport; fair-weather conditions prevailed throughout the experiment. During the winter experiment, which was intended to record the processes and consequences of a high energy event, two new sonar altimeters were added to Tripod I which was deployed at a depth of 8 m. Tripod II was placed very near at a depth of 7.3 m, the intent being to record the direction of migration of any possible sediment lobes. Two additional tripod deployments were made over Smith Island shoals on the shoreface fronting Virginia's barrier islands, over the periods August 17-25, 1987 and October 16-22, 1987. During the August experiment, Tripod I was deployed at a depth of 11 m and Tripod II was deployed at a depth of 10 m. Tripod I was deployed alone but also supporting the optical backscatter array in October.

Development of numerical models capable of simulating observed suspended sediment concentration profiles, bed level changes and cross-shore transport modes has taken place in parallel with field experimentation. For application to combined wave-current boundary layers, two versions of a two layer time-invariant eddy viscosity model permit estimation of the effects of sediment size, bedforms, and movable bed roughness and utilize observed flow velocities and wave characteristics as input. A diffusion model has been adapted to model suspended sediment concentration profiles for comparison with observed profiles. Cross-isobath transport of bedload is modelled in terms of the first three moments of the combined mean and oscillatory flow and bed level changes are modelled in terms of predicted sediment-flux divergences.

In other studies:

1) A study of the behavior and dispersal of turbid plumes from dredges was completed. This study was supported by the U.S. Army Corps of Engineers in connection with channel deepening for access for Baltimore.

2) The third and final cruise was successfully carried out in a study focused on the dynamics of extremely high suspended sediment concentrations. The study has used the shallow marine/estuarine environment off the mouth of the Yellow River in China as a natural laboratory and has provided insights into how silts are deposited from suspension in gravity driven underflows.



Members of the geological oceanography research team prepare to put a bottom-mounted, benthic tripod over the side.

PROGRAM XII
DESCRIBE AND UNDERSTAND THE CIRCULATION OF WATERS IN THE ESTUARINE AND COASTAL ENVIRONMENT.

John Posenau (left) and Karl Dydak deploy a dual frequency echo sounder.

Circulation Patterns. Studies in the lower James River have yielded a rather complete description of the general circulation patterns in that region. It appears that the fronts which form near Newport News Point provide a vertical linkage between the horizontal circulation near the surface and that near the bottom. Without that linkage, oyster larvae would likely remain in the surface layer and be transported out into Chesapeake Bay. The fronts, however, inject larvae (and other materials in the water) into the bottom layer where there is a net flow back upriver towards the seed oyster beds. Many larvae are returned to the seed beds where they can replenish the stocks.

Oysters are not the only marine organism to have a life stage wherein the animals, movement and distribution is controlled in large part by circulation patterns. Better understanding of the circulation could yield comparable insights for other species. Phytoplankton distributions also are greatly affected by circulation. Scientists are beginning studies to examine how circulation patterns relate to the development of water masses with low concentrations of dissolved oxygen, whether by concentrating dead algal cells or by low flows that are only weakly mixed. The role of the lunar cycle is being studied as well.

Mathematical Modelling. Contrary to most economic trends, the cost of computing power continues to decrease rapidly. One consequence is that mathematical models can become more complex, incorporate more realistic geometries, include more physical phenomena and generally simulate the natural environment to

a greater degree. Real-time, 3-dimensional models of water circulation in estuaries are the state-of-the-art.

VIMS scientists are participating in two major modelling efforts which focus on the entire Chesapeake Bay system and on the tidal James River. The former involves not only the movement of the water but also water quality. Water quality changes seasonally and water pollution control strategies may take years to become fully effective. Consequently, the model studies must include simulations lasting months; decade long simulations have been proposed. VIMS faculty are working with the U.S. Army Corps of Engineers on the coupling of the circulation and water quality models to ensure that the results are valid for both short and longer term simulations.

PROGRAM XIII
DEVELOP A BETTER UNDERSTANDING OF SHOREFACE, SURF ZONE, AND BEACH PROCESSES.

The objective of the program is to develop a better understanding of shoreface, surf zone and beach processes in order to provide more effective measures to mitigate shore erosion. As in previous years, effort has been shared between: 1) applied research and associated advisory activity aimed at dealing with the immediate and day-to-day problems of erosion along the shores of the Commonwealth; and 2) more basic research aimed at providing a deeper understanding of the fundamental mechanisms which operate to cause beach and shoreline changes.

The largest proportion of the applied shoreline research was conducted with support from the Virginia Department of Conservation and Historic Resources (DCHR). Under a formal memorandum of understanding between DCHR and the Institute, VIMS is responsible for conducting research into innovative low-cost erosion control techniques, providing technical advice to the Public Beach Commission and Shoreline Erosion Advisory Service (both of which are units of DCHR), and conducting research on the coastal dynamics and beach stability of shoreline reaches of the Commonwealth of Virginia. The applied research activities included field demonstrations showing that use of breakwaters for erosion control of estuarine shores is applicable to medium energy situations. In addition, an updated computer model incorporating the effects of refraction, shoaling, diffraction and energy dissipation by the combined effects of bottom friction and wave-current interaction was developed and applied to the Atlantic beach of Cedar Island on the Eastern Shore to predict longshore variations in breaker height, littoral drift, and beach stability. The model was also applied to selected reaches of Hampton and the James River.

Scott Hardaway (left) is assisted by graduate student Jian-hua Li in surveying a beach.

Increasing developmental pressures in the Commonwealth's coastal resort communities have focused attention on soft-structure approaches to erosion mitigation. Successful implementation of these measures is dependent on the identification and characterization of large deposits of beach quality sand. During 1987-88 an intensive reconnaissance study was performed in the Virginia territorial waters between Cape Henry and False Cape. Over 300 track miles of geophysical data and numerous sediment cores were retrieved in this area. Analysis of these data resulted in the identification of more than 50 million cubic meters of minable, beach quality sand. In addition, these data represent the most intensive survey made of the area and permit the investigation of several basic research questions, including: the morphological development of the inner shelf during the past 6,000 years; the effects of rising sea level on nearshore sediment bodies; and the role that antecedent fluvial topography has played on the subsequent development of Currituck Spit and its associated inlets.

A similar investigation was undertaken in the Tail of the Horseshoe reach of the Chesapeake Bay that resulted in the identification of more than ten million cubic meters of high quality sand. Through the application of the newly-developed hydrodynamic model, various possible dredging configurations were investigated to minimize adverse impacts of material removal.

The most significant basic research results obtained within the shoreface research program in fiscal year 1987-1988 are embodied in three Ph.D. dissertations completed during the period: 1) Kim, C.S., 1987, **Interaction of Long Waves and Nearshore Barred Topography**; 2) Green, M.O., 1987, **Low-Energy Bedload Transport by Combined Wave and Current Flow on a Southern Mid- Atlantic Bight Shoreface**; and 3) List, J.H., August 1988, **Long Wave Generation by Wave Groups in the Nearshore.**

Kim developed a numerical model, which he tested against field data, to predict the migration and persistence of longshore bars. The model accounts for the mass transport velocities induced near the bed by a family of long waves at surf-beat frequencies together with wind waves. Green utilized a combination of field experimental results from Duck, North Carolina and numerical modelling to explain and predict the onshore and offshore transports of sand seaward of the surf zone under the combined influence of waves and currents during fair weather. Green's model not only explains how beaches are nourished from offshore during fair weather, but also accounts, realistically, for observed shoreface bed-level changes. List also used a combination of field data and numerical modelling results to explain the roles that alternating groups of high and low waves play in forcing the long-period infragravity waves, or surf beat, which often dominate the surf zone energy regime during high energy events. The study demonstrates that a modified bounded long wave is the dominant group-forced mode, and may account for a large part of the infragravity band energy.

In other studies: 1) Field measurements revealed that two-dimensional nearshore bottom morphology is well represented by Dean's (1977) model of the beach equilibrium profile, $h = A x$, where h is depth below mean water level at a distance x offshore and A is a scale factor. Improved prediction of beach slopes and beach equilibrium profiles is an important practical result. 2) Analyses of nearshore sediment samples collected during two storm events over the Duck, North Carolina shoreface indicate foreshore accretion during the height of storm conditions with minor profile readjustment and deflation during the so-called "recovery" phase. Sediment distributions appear to be indicative of strong onshore transport during the storm events of material entrained from surface deposits seaward of the bar system.

Additional efforts during 1987-1988 included:

1) Initiation of a sediment inventory for Virginia's public beaches;

2) Continued monitoring and analysis of public beach profile characteristics; and

3) A study of the effectiveness of gabion structures for erosion mitigation in low-energy environments.

PROGRAM XIV
DESCRIBE AND EXPLAIN THE LATE QUATERNARY SEDIMENTOLOGY, STRATIGRAPHY AND GEOLOGIC EVOLUTION OF THE CHESAPEAKE BAY AND COASTAL WATERS.

The objectives of this program are to describe and explain the sedimentology and Quaternary geologic evolution of the Chesapeake Bay system and adjacent portions of the continental shelf to learn more about the region's geologic resources, such as heavy minerals, aggregate and shell, and about the long-term sources, sinks, pathways and processes for transportation of sediments and associated contaminants. This program is highly complementary to and interactive with the programs relating to the benthic boundary layer (Program XI) and to the development and utilization of marine resources (Program XV).

Fiscal year 1987-1988 was the final field year envisioned for the reconnaissance study of the occurrence and distribution of placer deposits of heavy minerals. In late July and early August of 1987 VIMS scientists participated in an eleven day cruise aboard the R/V ATLANTIC TWIN. We satisfied the cruise plan by acquiring 50 vibracores, maximum length 20 feet, from the inner shelf between Assateague Island and the North Carolina line. In addition to serving the minerals projects, approximately half of the cores also served the Virginia Beach sand exploration project. At the end of the fiscal year analysis of the samples for mineral content had been completed. The minerals work was enhanced by coordination with the Virginia Beach sand exploration study. In addition to the sharing of cores, there was a sharing of geophysical, sub-bottom and side-scan data. The joint effort allowed both projects to obtain more data than could have been acquired independently.

In addition to satisfying research contract requirements, the work on these projects has provided additional data and insights into the geology of the inner shelf, specifically the identification of filled channel systems crossing the shoreline and leading offshore. Advances were also made in the search for fossil shell. Early in the year Parker's Rock Shell Study that was funded by VMRC was completed. Although the coring was done in June 1987, the work-up and analyses were done in fiscal year 1987-1988. Since receipt of the project report, VMRC has proceeded with plans to dredge shell for use in the replenishment program from the area.

VIMS vibra corer for taking sediment cores.

PROGRAM XV
CONDUCT INVESTIGATIONS RELATED TO THE DEVELOPMENT, UTILIZATION, AND MANAGEMENT OF RESOURCES OF SIGNIFICANCE TO THE MARINE ENVIRONMENT.

One of the objectives of this research program is the development of management strategies for the conservation and/or development of Virginia's living and non-living marine resources. These resources are affected by activities and other resources that are beyond what is traditionally considered the marine environment. To fulfill effectively the mandate expressed for the Institute, comprehensive studies must be pursued and result in recommendations useful to the management of these marine resources. Inherent in such a

research program is the need to evaluate, modify, and develop scientifically, economically, socially, and legally sound resource use strategies for individuals and institutions involving the Commonwealth's living and non-living marine resources.

Feasibility of the Assumption of the Clean Water Act's Section 404 Regulatory Authority By Virginia. An investigation of the feasibility of the assumption by Virginia of Section 404 regulatory authority under the Clean Water Act continued. This investigation, funded by the U.S. Environmental Protection Agency, assesses the impediments, advantages and disadvantages associated with Virginia seeking to simplify wetlands permitting requirements by assuming Section 404 regulatory authority. To date, a legal analysis of the statutory and regulatory requirements for Section 404 assumption has been completed. Through the use of a questionnaire directed to relevant state and federal agencies, environmental groups, wetlands boards and other states, opinions on the feasibility of Virginia's assumption and administration of a 404 regulatory program have been obtained and are currently being analyzed. The investigation will identify advantages and disadvantages of Virginia's assumption of Section 404 regulatory authority, identify additional legislation necessary for Virginia to comply with federal requirements for assumption, identify an appropriate state agency structure and responsibilities for Section 404 oversight in Virginia, identify costs and sources of funding at state and federal levels for the delegation and implementation of Section 404 regulatory authority, and provide recommendations regarding the feasibility of Virginia assuming Section 404 regulatory authority.

Recommendations for Aquaculture Legislation. Research efforts leading to the development of recommendations for aquaculture legislation continued. Legal, policy, and institutional impediments affecting the development of Virginia's aquaculture industry were identified. Recommendations for removing or mitigating these impediments have been drafted. If successfully implemented, legislative changes should enable the Commonwealth to more effectively realize the economic potential of marine aquaculture and encourage the development of new technologies.

Estuarine Research Reserve System for Virginia. Activities continued on the development of an Estuarine Research Reserve System in Virginia's Chesapeake Bay. Although the staff is assessing sites in all of the main tributaries and the mainstem of Chesapeake Bay, the principal focus has been on the York River Estuary. Four sites, Goodwin Islands at the mouth (York County), Catlett Islands in Gloucester County, Taskinas Creek in York County (part of the York River State Park) and Sweet Hall Marsh in the Pamunkey River (King and Queen County) were selected for additional consideration. If no objection arises regarding these sites, they will be nominated for inclusion into the National Estuarine Research Reserve System as the initial phase of Virginia's complete system.

Preparing a detailed map of marsh vegetation patterns.

Monitoring

Bringing the trawl doors on board.

PROGRAM I
FISHERIES

Anadromous Fishes. The major objective of this monitoring program is to maintain a long-term data base on anadromous fishes in order to understand the population dynamics of these species as well as to assist in basic research of individual species. In turn, the data are used in advisory services, basic research, and population dynamics studies. The anadromous projects, in conjunction with those of other states investigating Alosa and striped bass stocks, contribute to the general knowledge necessary for evaluation of rational management alternatives, both in Virginia waters and coastal waters of the eastern United States.

The Alosa stocks (American shad, alewife and blueback herring) and their fisheries in Virginia were evaluated by sampling adult Alosa taken from the commercial catches in the James, York and Rappahannock rivers during the spring spawning migrations. Individuals of each species were sexed, and lengths and weights recorded. Otoliths and scales were also taken for aging each specimen. Juvenile (young-of-the-year) Alosa were sampled with a specially designed pushnet developed at VIMS. Indices of abundance for juvenile Alosa, derived from catch and effort data, were compared to previous annual indices.

Adult striped bass were collected from commercial fisheries in the York, Rappahannock and Potomac rivers to characterize the composition of catches in gillnets and pound nets by sex age, length and weight in the spring and fall-winter fisheries.

Juvenile Striped Bass Research. Monitoring of the relative annual abundance of juvenile (young-of-the-year) striped bass (rockfish) in the Virginia nursery areas was continued for the eighth consecutive year and fifteenth year since 1967. Sampling is conducted during the summer months with a 100 foot beach seine. Results of the 1987 survey were extremely encouraging, as record high index values (average catch per seine haul) were recorded for all three of the major nursery areas sampled (James, York and Rappahannock rivers drainage basins). The overall index value (15.8) was over five times the previous historical average. This continues a trend of improving recruitment seen in recent years which not only provides an apparent early indication of a possible recovery of the Virginia populations of striped bass, but also greatly alleviates concerns that water quality in these systems has declined to levels which are non-supportive to successful reproduction of this highly prized game and food fish.

Unfortunately, this situation remains in sharp contrast to the situation in the northern portions of Chesapeake Bay, where the recruitment index continues to lag well behind the historical average. Firm conclusions as the present status of the Chesapeake Bay stock of striped bass as a whole will have to be reserved until either a similar rebound is observed in the Maryland and Potomac striped bass spawning areas or the relative contribution of the various spawning areas to the overall population are more fully understood. Subsequent monitoring of the 1987 year class should provide insight into this last question.

In addition to the regular survey, considerable supplementary sampling was continued in an effort to better understand juvenile distribution patterns and the effect of these patterns on survey results. Investigations into environmental influences on growth and survival of first year striped bass are also in progress.

Oyster Monitoring. A time-series analysis of monthly oyster condition index was completed for the period 1970-1984 for the three major Virginia tributaries to the Chesapeake Bay. Condition index of oysters is the ratio between the available shell volume and the amount of space the oyster meat actually occupies. Interannual variation is statistically explained by fluctuations in temperature and river discharge. River discharge was used as a surrogate for salinity.

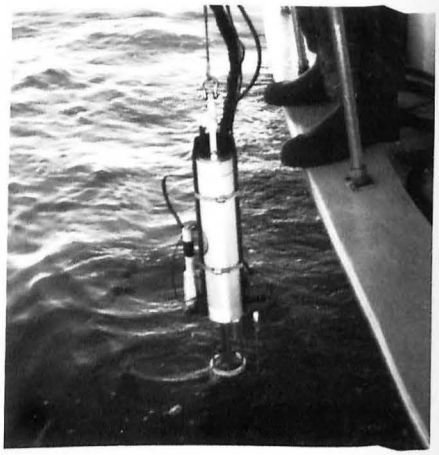
Most significant is the long-term trend which shows a greater than 20 percent increase in the James River and a greater than 25 percent decrease in the Rappahannock River. These differences may be explained by changes in circulation that have resulted in increased episodes in hypoxic conditions in the lower Rappahannock River. During hypoxic events the oysters remain closed and metabolize their body stores. Consequently a reduced condition index may be a result of increasing hypoxia in the Rappahannock.

Spatfall Monitoring Program. The oyster settlement monitoring program builds on a data base that started over forty years ago. At weekly intervals during the oyster spawning and settlement season (approximately June through late September) "strings" of clean oyster shell are deployed at fixed locations on the Eastern Shore and throughout the tributaries of the Bay. These are retrieved one week later and replaced with a further "string" of shells. The retrieved shells are examined microscopically for the presence of newly settled oysters. Oyster settlement in 1986 was the lowest in seven years; however, settlement was generally higher in 1987 with the exception of the Mobjack Bay area and the Virgina shoreline of the Potomac River. In the James River oyster settlement was high and sustained from early July through late September. A continued good settlement is required for recovery of the fishery. The interannual variability in settlement is cause for concern. Further, post settlement losses of newly settled oysters continues to be worrisome in that settlement often occurs in downstream, high disease locations. By the fall of 1987 bottom surveys of oyster rocks indicated that significant bushel counts of surviving juvenile oysters could only be found in the upper James and Great Wicomico rivers.

Stock Assessment. Work funded by the Chesapeake Bay Stock Assessment Committee has continued to develop computer-compatible weighing/measuring boards to effectively capture data. Their use was initiated in January in support of trawling studies in the mainstem Chesapeake Bay; the initial six months of use suggests these boards promise to minimize data entry errors and provide a long-needed ability to conduct rapid, timely data analyses. Computer programs have been developed to provide completely randomized, and stratified random, trawl station selection in the main stem Chesapeake Bay and in its major tributary rivers and bays except for the James River; this will greatly enhance the scientific soundness of monitoring programs.

The long-term series of routine surveys for fish and blue crabs has been continued.

PROGRAM II
PLANKTON



A salinity, temperature and depth profiler combined with a dissolved oxygen probe is deployed from a VIMS vessel.

Phytoplankton Monitoring. The primary objective of the phytoplankton monitoring program is to elucidate long-term trends in species composition and abundance at a site in the lower York River. This on-going effort takes on special importance in light of a phosphate detergent ban adopted by the Commonwealth which became effective on January 1, 1988. Preliminary indications from municipalities and regional sanitation districts are that the phosphorus content in both the influent and the effluent of sewage treatment plants in the coastal zone has decreased on the order of 25 to 30 percent. It remains to be seen whether this reduction in phosphorus inputs will have any effect on the phytoplankton community. Although data from 1988 can be compared with prior years, inter-annual variations also are large. Several additional years of monitoring will be necessary before it is possible to assess the impact of the ban on phytoplankton processes.

In 1988 there was no hiatus between the spring and summer sampling conducted from the pier at the United States Coast Guard Reserve Training Center in Yorktown, Vir-

ginia. Sampling continued throughout this period because an array of particle interceptor traps had been placed in the lower York River to measure the rate at which suspended particulates, including phytoplankton, sink out of the water column. These measurements were made at three depths in the water column. Comparisons between water samples collected near the traps and those collected from the Coast Guard pier will elucidate spatial variability of phytoplankton abundance in this estuary. Comparisons between particulate abundance in the water column and in the traps will provide information on the contribution of phytoplankton to the flux of organic carbon to the river sediments. The decomposition of this organic carbon in the sediments is a factor that affects the dissolved oxygen content of the overlying water. (See Research Programs III and X.)

PROGRAM III
BACTERIA (LOWER YORK RIVER)

Monitoring Bacteria in the Lower York River. Seasonal bacterial surveys of the lower York River were continued to determine densities of indicator bacteria, heterotrophic and petroleum-degrading bacteria in the water column and sediments. Selected river sites were also monitored for the human enteric pathogens *Salmonella* sp. and *Yersinia* sp. Both these organisms have been recognized as potential pathogens which may be transmitted through consumption of raw shellfish. These organisms were frequently isolated from the lower York River, but at densities which do not appear to pose a public health threat. Their presence was not predicted on the basis of fecal coliform indicator densities. The contents of the lower York River bacterial data base have been made available to NOAA for incorporation into a national data base.

PROGRAM IV
PARASITES AND PATHOGENS

Shellfish Diseases. During 1987, 2,425 oysters (97 samples) were analyzed for MSX and 2,250 oysters (90 samples) were analyzed for *Perkinsus marinus* (previously called Dermo).

The year 1987 was the third year in a row of severe drought in the Chesapeake Bay region and the resulting increase in oyster disease distribution and abundance was dramatic. James River disease susceptible oysters held in trays at VIMS developed the highest prevalence of MSX ever recorded in 28 years of continuous monitoring. During the monitoring period from May to December, 78 percent of the oysters in the tray died from MSX—the highest mortality value on record. MSX caused significant mortality in native oysters in Pocomoke Sound, the Rappahannock River, the Great Wicomico River, Mobjack Bay, and the lower James River. MSX was also abundant at Wreck Shoal in the James River seed area and caused serious mortality in that area.

The spread and intensification of *Perkinsus marinus* during 1987 was unprecedented. Beginning as early as June, prevalence of 90 percent or greater occurred on all public oyster rocks sampled in most of the traditional growing areas, including Wreck Shoal in the James River seed area. Only the upper James River was free of *Perkinsus* during 1987. A high proportion of infections were ranked heavy or moderate indicating ongoing mortality. Private oyster grounds in Potomac River tributaries also experienced high losses from *Perkinsus marinus* for the second year in a row.

The combined oyster mortality from the two diseases was estimated at between 70 and 90 percent for public grounds in the Virginia portion of Chesapeake Bay, excluding the upper James River. This high mortality caused a shift in harvest pressure from the traditional public grounds to the James River seed area, the only area in Virginia with sufficient oysters for profitable harvesting.

PROGRAM V
BENTHIC INVERTEBRATES

The objective of this program is to follow the natural population dynamics of the soft bottom invertebrate communities. These community data then provide a record of the long-term changes that occur in the Chesapeake Bay system. They also provide a reference point from which to assess the impacts of man's activities. The natural ecosystem is inherently variable through time with temperature, salinity and wave energy changing on time scales of hours to months. Long-term data are needed to accurately separate community changes into those that are part of the natural variability of the Chesapeake and those that are man-induced.

At the long-term monitoring station in the lower York River that has been sampled since 1960, the communities continue to change in different ways. At no time in the last 27 years have the communities repeated themselves exactly. Dominant species, in terms of numbers and biomass, continue to change yearly. This year, with the continued low rainfall, the trend of increasing numbers of higher salinity species has continued. This trend has been evident for the last five years and may reflect the climatic events in the Bay's watershed.

PROGRAM VI
ESTUARINE PLANT COMMUNITIES

Tidal marsh

The distribution and abundance of submerged aquatic vegetation (SAV) was mapped for the entire Chesapeake Bay and its tributaries and Chincoteague Bay in 1987 using color aerial photography at a scale of 1:24,000. Groundtruth information was available from the U. S. Geological Survey, Maryland Department of Natural Resources, University of Maryland, Horn Point Laboratory, Harford Community College and VIMS. Citizen support via the Chesapeake Bay Foundation and Citizens Program for the Chesapeake Bay, as well as Maryland's Charterboat Association via Maryland's DNR Watermen's Assistance Program, provided additional groundtruth support.

In 1987 the Chesapeake Bay had 19,782 hectares of SAV, with the upper, middle and lower Bay zones having 2954, 4970 and 11,858 hectares, respectively. The total abun-

dance is similar to that reported for 1986.

SAV continues to be very sparse on the Susquehanna Flats, an area that historically supported a significant population of submerged grasses. Smaller beds of SAV are present along the shoreline adjacent to the Flats region.

Widgeon grass, *Ruppia maritima*, a species that has a tolerance to a wide range of salinities, has continued to show a rapid increase in many sections of the Bay, particularly those in the middle and lower Bay zones. *Ruppia* was observed in several locations in both the Rappahannock and Piankatank rivers in 1987 where no SAV has been observed in the previous 15 years. Some of these stands were very dense and are currently being monitored for population structure. *Ruppia* appears to be colonizing these areas by seed propagation.

Hydrilla verticillata continues to be the dominant species in the upper Potomac River section. Although this species continued to expand its range downriver, the overall abundance of SAV in this section did not change significantly from 1986 (1,655 ha in 1987 vs. 1,673 ha in 1986). This abundance is contrasted to the 1978 survey when no significant SAV beds were present in this section.

SAV in Virginia, which is in the lower Bay zone, is abundant along both the eastern and western shores in the following locations: Eastern Shore at the mouths of the Cherrystone Inlet, Hungars Creek, Mattawoman Creek, Occahannock Creek, Craddock Creek, Pungoteague Creek, Onancock Creek, and Chesconessex Creek as well as in broad shoal regions around Great Fox Island and between Tangier and Smith Island; western shore—Back River, Drum Island Flats, Poquoson River, lower York River, Mobjack Bay, Horn Harbor, and the Corrotoman River. *Ruppia maritima* and *Zostera marina* (eelgrass) are the two dominant species in Virginia, although *Zannichilia palustris* (horned pondweed) is locally abundant in the spring.

Abundance of SAV in the Chincoteague Bay area in 1987 (2,310 hectares) was similar to that recorded for 1986 (2,135 hectares). Abundant stands are present at the northern end of Chincoteague Island, West Bay, Green Run Bay and Tingles Island. *Ruppia maritima* and *Zostera marina* are the two species that occur in this area.

Tidal Marsh Inventory Program. The Virginia Institute of Marine Science is mandated in the Wetlands Act of 1972 to evaluate, classify and inventory tidal wetlands in the Commonwealth.

An evaluation and classification system was established in the early 1970's and published in a report titled **Coastal Wetlands of Virginia:Wetland Guidelines** Interim Report No. 3 in 1974. The publication was later promulgated by VMRC as **Wetland Guidelines.**

The wetland inventory program began in 1972 and continued until 1981 when budget shortfalls made it impossible to support the program. In this time period, 23 reports were published and distributed, totalling 13,000 copies.

The marsh inventory reports are an integral part of the wetland resource management program in the Commonwealth. They are utilized by local wetland boards, state and federal agencies, developers, utility companies, marine contractors, consulting firms, planning commissions and environmental organizations.

Beginning in July 1987, funding was provided by the General Assembly for a laboratory specialist to begin work on the tidal marsh inventory program. Funds were also provided from the Council on the Environment (COE) and Coastal Resource Management (CRM) to increase the inventory operating budget. As a result of these enhancements, three wetland inventory reports were published in 1987: the City of Norfolk; Prince William County; and King and Queen County. A revised marsh inventory was completed during this period utilizing aerial photographs obtained via a grant from Isle of Wight County/ COE/CRM. Isle of Wight County is the first in a series of our revised inventory program.

Groundtruthing, data reduction and digitizing is now underway for the cities of Chesapeake and Portsmouth, and Prince George County.

PROGRAM VII
COASTAL EROSION

The objectives of this program are to measure and monitor tidal shoreline changes in terms of erosion rates, land use and anthropogenic effects in the Commonwealth.

In fiscal year 1987-1988 an administration manual and technical report were prepared to assist users of the Shoreline Inventory Computer Database. In addition, the Chesapeake Bay Shoreline Study, a monitoring project, began in July 1987 with the goal of evaluating the effectiveness of gapped offshore breakwaters in controlling shore erosion. These breakwater systems may offer a lower cost means of shore protection. This study is a collaborative effort involving the U.S. Army Corps of Engineers, VIMS, and Department of Conservation and Historic Resources.

PROGRAM VIII
PHYSICAL AND CHEMICAL

Jimmy Greene takes a fish tissue sample for chemical analysis.

Effluent Monitoring. The second biannual report detailing the results of a four-year study performed in conjunction with the Virginia Water Control Board to examine sources of toxic organic compounds to the Chesapeake Bay and its tributaries has been completed. Outfalls chosen for examination included those from sewage treatment plants, specialty chemical producers, petroleum handling and refining operations, federal installations, shipbuilding/repair operations, creosoting plants, and electrical power generators. The procedures used allowed the detection of an array of pollutants, some of which have not been recognized as occurring in the Chesapeake Bay. Most current approaches for the determination of anthropogenic compounds in the environment rely on preconceived lists of "priority pollutants," i.e., only those compounds present on the list in question will be sought. Unfortunately, the diversity of contaminants in the environment is tremendous and toxics are frequently site specific. Therefore generic methodologies often fail to identify critical pollutants. The results obtained during

the "Pilot Toxics" program illustrate the need for the deployment of more comprehensive analytical techniques, if the health problems of the Chesapeake Bay are to be remedied. A specific example of the usefulness of the "Pilot Toxics" approach is the discovery of a group of compounds known as polychlorinated terphenyls (PCT). These compounds are chemically similar to PCB; however, comparatively little is known concerning their occurrence, fate and toxicological effects. Two discrete families of PCT were detected at high concentrations near federal installations and shipbuilding/repair operations. Their environmental significance is under investigation.

The "Pilot Toxics" program examined effluents, as well as associated sediments and shellfish for the presence of pollutants. Biota were available at only 20 percent of the locations, due to the presence of unsuitable environmental conditions. Detectable levels of anthropogenic compounds were found in 28 of the 30 effluent samples examined. Seventy-five percent of the sediments, collected in the vicinity of the outfalls, contained measurable concentrations of effluent associated pollutants. Effluents at the remaining 25 percent of the sites contained minimal levels of anthropogenics. Several instances were observed in which high concentrations of pollutants were present in the sediments, but not reported in the corresponding effluents. This may be due to cessation of releases, sporadic releases or additional input from unsampled sources. In any event, this sediment associated material was present within the aquatic system and available for possible further dispersal or mediation of toxic effects. The information obtained from this study is being used to modify current regulatory practices and to pinpoint critical research needs.

Virginia Water Control Board Data Base. A computer database of organic compounds and metals in Virginia's aquatic environment has been established. Concentrations of chemicals in some 150 sediment, biological tissue, industrial effluent and water column samples are already accessible at the VIMS Computer Center. Data retrieval programs allow keyed searches of the database through terminals at VIMS or by telephone link. Existing Water Control Board historical data as well as new data generated at VIMS and other contributing laboratories are regularly incorporated to provide a background baseline as well as current information on the chemical compounds in Virginia's waters. Database searches have produced useful correlations in the spread of certain compounds from point source effluents to adjacent sediments and organisms.

Tributyltin Research. Tributyltin (TBT) is a biocide used in many formulations of antifouling paints. It is toxic to some aquatic species at concentrations less than ten parts per trillion. VIMS initiated a TBT water monitoring program in January 1986 and is continuing to collect and analyze samples from marina areas. This TBT water data set is the most extensive one in the world and will allow scientists to gauge the effectiveness of state and federal laws restricting TBT usage. In addition, analytical methodologies for TBT determinations in sediment and tissues have been developed. VIMS is using these to analyze for the biocide in sediments and oysters. Concentrations of over one part per million have been detected in both mediums in areas of high boating activities. The James River and Hampton Roads consistently contain elevated levels.

Early Warning—Chlorinated Hydrocarbons. The objective of this research is to provide baseline information on chlorinated hydrocarbon concentrations in seafood harvested in Virginia waters. The chlorinated hydrocarbons include PCB, pesticides and industrial compounds. These chemicals may affect the quality of those estuarine organisms which comprise Virginia's seafood resource.

A unique aspect of the Early Warning System Design is the capability to track unidentified compounds in seafood samples. This can be followed by efforts to identify these unknown compounds and determine if a potential threat to public health exists.

One hundred fifty-four samples collected from the James River, lower Chesapeake Bay and Eastern Shore of Virginia were analyzed. The species analyzed include bluefish, trout, striped bass, white perch, spot and eel.

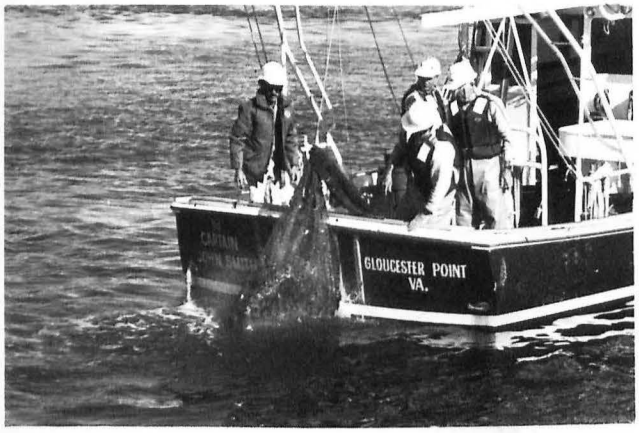
Fish samples from the James River have in preceding years contained higher levels of PCB and pesticides than samples from other areas. This again was the case. However, PCB concentrations were less than the FDA action level of 2.0 ppm.

A compound of unknown structure and origin has been present in numerous samples from the James River. This unknown compound is being monitored in various species of finfish. Much time and effort have been spent developing techniques to isolate the unknown compound from the sample matrix for mass spectrometric analysis. Efforts are continuing in this direction.

Kepone. The levels of Kepone in selected fishes and sediments from the James River were monitored in cooperation with the State Water Control Board. This year VIMS analyzed over 650 samples for Kepone residues.

Residue levels in fishes have shown considerable decline over the last several years and as a result the ban on commercial fishing for selected species was removed effective 1 July 1988. Continued monitoring of Kepone levels in the James River will, however, be necessary for some years to assure that public health is protected and to provide a long-term record.

Research on Kepone indicates that it can produce chronic and acute effects on marine and freshwater animals. However, the levels necessary to cause adverse effects appear to be considerably greater than those found in the James River.



Preparing to bring a trawl net on board the R/V CAPTAIN JOHN SMITH.

Advisory Activities

The seafood seminar program continued to be very popular in 1987-1988. Chef Jimmy Sneed (left) looks on as Bill DuPaul (VIMS) shows Joe Flannigan (center) how to shuck a scallop.

ACTIVITIES OF MARINE ADVISORY SERVICES

Marine Advisory Services' (MAS) work this year culminated in direct benefits to the many marine-related industries of Virginia. MAS's continuing role is to directly respond to immediate and long-term needs of marine industries and private citizens; comprehensive programs in commercial fisheries, marine-related trades, recreation, education and communication are offered.

Scallops. Sea scallops continue to be the most valued seafood harvested in Virginia. Marine Advisory Services has intensified efforts to maximize Virginia's share of this important resource. Last year Virginia landings reached an all-time high of over eight million pounds valued at 28 million dollars. Sea scallops are not only the most highly valued commercial species in the State, but the mid-Atlantic region also lands about 40 percent of the average national catch.

Research supported by members of the MAS and the East Coast Fisheries Association has started to alter some long held perceptions of both the fishery and the biology of the sea scallop. For example, managers typically used a simple shell size/meat count ratio which is designed to serve both management and conservation. Preliminary data figures indicate this may prove an overly-simplified approach for this fishery. The cyclic nature of the fishery is of concern to both resource managers and industry, and several research projects resulted in regulatory changes.

Research in this realm involved examining spawning cycles, areal and seasonal differences in meat yields, and associated ramifications for management and enforcement. As a direct result of this study, the meat count regulation was modified on a seasonal basis. At the request of industry, MAS conducted technical and analytical support to determine the size selectivity of sea scallops harvested by a traditional and modified dredge and trawl gears. The object of these studies is to maximize the harvest of large scallops and to minimize the harvest of undersized scallops.

Other topics of interest to the scallop industry being addressed by MAS include loss in meat integrity and product deterioration. These problems may relate to established at-sea handling practices. Scallop handling practices were monitored on an initial 15-day trip on a local scallop vessel. The temperature history of scallop meats was also recorded from time of landing on-deck, through washing, bagging, stowage and off-loading. Alternate handling procedures which could result in improved quality and increase product value are being investigated.

Containerized Relaying of Hard Clams. As a direct result of research, advisory services and industry efforts, State approval was granted in 1987 for the relaying of polluted clams by cages. The containerized relaying of hard clams

revolutionized this portion of Virginia's clam fishery by reducing industry losses from 20 to 30 percent to a more acceptable five percent.

A relay system, as it is called in the industry, involves taking clams from polluted beds and placing them in areas free of contaminants. Clams, which are filter feeders, pump large volumes of water through their bodies. Consequently, replanted clams can be harvested 15 days after replanting. Before the development of the cage relay system, clams were replanted through on-bottom placement simply dropping the clams overboard. This practice is still done, but the use of cages maximizes fishermen's efforts by ensuring they will be able to recover all of the replanted clams. Fewer men can harvest more clams in a shorter time, and because containerized clams do not come into direct contact with sediment, they are cleaner and do not have a grit problem. In short, a better recovery rate, the ease of recovery and the better overall clam appearance translates into a substantial advance for this industry.

VIMS's program began modestly with two containers. Estimates for the number of containers in use for 1988 are between 1,000 and 1,250. Six firms are currently permitted to use containers and permit applications are received almost daily by the Virginia Health Department (VHD). Estimates by State health officials are that the number of clams relayed this year tripled by June and may approach 50 million clams by the end of the season. VHD attributes this growth solely to the use of containerized relaying. This increase in production represents not only a bonanza for watermen harvesters and clam relay operators, but a better utilization of the clam resource through increased survival during the relay process.

Seafood Seminars. The very popular Seafood Education Seminars conducted by MAS completed its fifth series of sell-out classes. This program combines the expertise of Tidewater chefs with Virginia wine specialists. Seminars focus on the health benefits and the ease of preparing Virginia seafood at home. A marine scientist from VIMS participates in each class and promotes a particular seafood; harvesting techniques and seafood preparation are explained. The positive economic impact on Virginia's economy through increased seafood consumption is also discussed.

Seafood Education Seminars were featured in both the newspaper and television markets. There were regular television appearances by VIMS scientists and advisory personnel in areas of research, conservation and resource education. As a result of MAS's efforts, the possibility of developing a television special with WVEC-TV 13 is being explored.

Scallops

Marine Education. For the second year, advisory education personnel coordinated the National Youth World of Water Awards Progam, which is sponsored by the National Marine Educators Association. This program provides students, who have won science fairs at the local, State or regional levels, the opportunity to achieve national recognition for their water-related projects.

In spring of 1988, an internationally acclaimed program featuring "Mr. and Mrs. Fish" was at VIMS to perform for Gloucester County Elementary Schools. There was also a program for the general public. Five 60-minute presentations entitled "Tails of the Chesapeake" depicted how sea life survives in the harsh marine environment.

Education is an integral part of efforts to restore and preserve the Chesapeake Bay. As the local population grows and stresses on the Bay increase, the support and participation of citizens will become increasingly important. The Bay Team, MAS specialists who disseminate current and useful information to students, teachers and the general public, encourages continued interest in water resources. The Bay's future will, in many ways, be dependent on the knowledge and sensitivity of tomorrow's decision-makers. With this in mind, the Bay Team's objective is to educate schoolchildren, teachers and the general public.

Currently, many students are not knowledgeable about the problems facing Virginia's estuarine systems. They cannot reasonably be expected to be aware unless appropriate learning opportunities are provided. This year the Bay Team came into contact with 50,000 students and provided information packets for all their teachers. Instruction focused on the Bay ecosystem and its importance to Virginia.

Education programs are designed to help students understand both individual and management practices necessary to the health of the Chesapeake Bay estuarine system. Learning activities were developed to meet Virginia's standards of curricula and the Bay Team provided teachers with follow-up activities.

Education specialists within the department continue to assist the Virginia Resource Use Education Council in presenting four graduate level education courses for teachers each summer. The Education Coordinator chairs the Course Committee for the council and arranges for marine science instruction and field study.

For the fourth year, Marine Advisory Services hosted the Virginia NASA/VIMS Governor's School, a six-week summer program for gifted and talented Virginia high school students. This program, sponsored by the Virginia Department of Education, matches students with scientists who volunteer their time to act as mentors for the students. Twenty students participated in the VIMS program.

Soft Crabs. MAS continued to be one of the leaders in the development of the soft-shelled blue crab industry on both the local and national level. The Second National Symposium on the Soft-Shelled Blue Crab Fishery was held at VIMS in late 1987 bringing together scientists, advisory/extension personnel and industry participants for an open exchange of the most recent developments in soft crab production. In addition, the popular "Manual on Handling and Shedding Blue Crabs" was revised to reflect new or changing technology. Requests for assistance in establishing shedding facilities are routinely received from all over the United States and from foreign countries.

Advisory Services provides essential technical assistance to the soft

crab shedding industry, with emphasis on the maintenance of water quality parameters in closed, recirculating systems. The production of soft crabs continues to expand as the demand for this gourmet item increases. Technical advances in system design and maintenance provided to industry have led to a decreasing number of shedding-related mortalities and an increase in shedding capacity per system.

Increasing production capabilities of the soft-shelled blue crab industry fall into three basic categories: basic education, diagnostic services, and shedding facility design/construction.

In addition to disseminating information, on-request diagnostic services were continued this year. Also, considerable efforts were devoted to facility design and construction. These projects entailed offering services to people interested in entering the industry as well as people seeking to update their current systems. For new industry members, facilities were designed, assistance given in lay-out and construction, and information provided on marketing.

Updating activities involved providing assistance in changing from traditional in-water shedding floats to on-shore systems and conversions from flow-through systems to closed, recirculating systems.

Recreation. Recreational fishing is a growing and vital concern in Virginia. In addition to being an ever-expanding area, recreational fishing activities provide a common bond among people who live and work in Virginia's coastal areas. Artifical reef and pelagic fishery studies, involving catch and effort data gathering, by MAS involved weekly contact during the fishing season with charter captains, marina/tackle shop operators, corporate executives, retirees, service industry workers, government employees on all levels and other people who fish for recreation as well as those who depend upon coastal fishing for a livelihood.

Program objectives have been:

- To maintain a diverse, responsive program capable of addressing concerns and informational needs of major coastal recreational audiences.
- To fill existing data voids relating to significant water-dependent recreational activity and resource management issues in coastal areas (i.e., boating, fishing, diving and community waterfront development).
- To initiate or co-sponsor seminars, workshops and conferences addressing key issues of concern to coastal recreational industry and user groups.

Growing interest and participation in recreational fishing and boating by Virginians mean increased pressure on fishery resources and on coastal waterfront areas. Concerns focus on impacts of fishing pressure and the possible need for size limits/catch limits on species. These issues, and the possibility of conflicts between recreational fishermen and commercial fishermen, have resulted in numerous demands on the recreational part of MAS to supply up-to-date information on the life-history and fishery management aspects of various species. State, regional and international fishery management agencies are also requesting information on the magnitude of certain fisheries and the socioeconomic aspects of particular fisheries. While the MAS depends upon fishery researchers and existing literature for much of the information necessary to satisfy these demands, MAS is also actively involved in collecting data on certain fisheries to fill voids in existing information bases.

The MAS program plans to continue its role in facilitating the communication process between recreational and commercial fishermen and to work toward what is the best for the fishery resource. The MAS sponsored Sport Fishermen's Forum serves that end; information is exchanged on research, management issues and recreational-commercial fishery conflicts.

ACTIVITIES OF RESEARCH STAFF

Advisory Services

Fisheries. Fisheries scientists continued to hold memberships on the Scientific and Statistics Committees of the Mid-Atlantic Fisheries Management Council (MAFMC). They also hold appointments to the Striped Bass, Bluefish, Shad and River Herring, Menhaden, and Weakfish scientific and statistics committees of the Atlantic States Marine Fisheries Commission (ASMFC).

Active membership on advisory committees includes the Advisory Committee for the Atlantic States Marine Fisheries Commission, Fisheries Management Advisory Committee, Virginia Marine Resources Commission, (VMRC), and the Legislative Advisory Committee, Potomac River Fisheries Commission (PRFC).

The Governors' Agreement, signed in December 1987, committed the Bay states to several resource management programs. Committees, subcommittees and work groups were formed to develop plans and implement the management strategies. VIMS fisheries scientists serve on several of these which include: the NOAA Chesapeake Bay Stock Assessment Committee (CBSAC); Status of Stocks Knowledge Work Group (CBSAC); Living Resources Subcomittee (EPA); Monitoring Subcommittee (EPA); and the Monitoring Work Group, Living Resources Subcommittee (EPA).

Wetlands. In response to the Institute's educational and advisory mandates, personnel of the Wetlands Advisory Group are an integral part of the Commonwealth's Coastal Resources Management Program (CRMP). Their efforts include: scientific and technical review of shoreline permit applications; the coordination of the Institute's responses to environmental impact statements [both the State program and the National Environmental Policy Act (NEPA)]; and the review of National Pollutant Discharge Elimination System (NPDES) permit applications. Personnel are also active in the development of legislation and management guidelines pertaining to wetlands, dunes and Bay protection in general as well as conducting training sessions, educational seminars and workshops for environmental managers. This educational effort affords those charged with regulatory responsibilities with the opportunity to acquire the basic scientific knowledge necessary to carry out their management objectives.

More specifically, Wetlands Advisory Group personnel serve as scientific and technical advisors for review of permit applications for wetlands, coastal primary sand dunes and subaqueous lands. The scientists reviewed approximately 1906 shoreline applications and responded to numerous requests from citizens for pre-application advice. Because of the significant annual increases in numbers of applications received since 1983, two additional marine scientists were added to the wetlands staff in July 1987.

Personnel of the Wetlands Advisory Program also coordinated Institute comments on seven environmental impact statements including the U. S. Navy's Empress II (an electromagnetic pulse simulator),

(an electromagnetic pulse simulator), the Horn Harbor dredging and beach nourishment project in Mathews County, and the Ware Creek Reservoir in James City County. Personnel continued the review and coordination of National Pollutant Discharge Elimination System permits as requested by the State Water Control Board. A major effort went into the continuing development of wetland mitigation/compensation guidelines for use by the Virginia Marine Resources Commission and the local wetlands boards. As part of the advisory mandate, wetlands personnel attended the regular meetings of the following groups which generally meet monthly: State/Federal Joint Permit Processing Group; Local Wetlands Boards (31); U. S. Army Corps of Engineers (federal dredging project reviews); Virginia Department of Transportation Environmental Coordination; and the Virginia Marine Resources Commission.

The Wetlands Advisory Group received via Virginia's Coastal Resources Management Program funds for the purchase and operation of a shoreline permitting data retrieval software package. The long-term objectives are to increase the efficiency of permit review, report generation and tracking, and to provide a link between advisory and research efforts by facilitating access to advisory program data bases. The software package, Info/Text, has been loaded on the mainframe at VIMS. Efforts are now being made by computer personnel to make Info/Text compatible with Wordmarc Composer so that the staff can utilize its report generation capabilities. All members of the wetlands advisory staff have been provided with IBM compatible PC's which are also in communication with the mainframe.

Wetlands Advisory Group personnel were also called on throughout the year to participate in the studies and other activities conducted by the Center for the Study of Estuarine Resource Management and Policy. Of particular interest were legislative activities regarding non-tidal wetlands and a comprehensive shoreline erosion policy for the Commonwealth.

Chesapeake Bay Program. Institute staff continued to play key roles in providing scientific and technical advice on a wide variety of Chesapeake Bay Program issues. The Dean/Director and Associate Dean serve on the Scientific and Technical Advisory Committee (STAC) established by the Chesapeake Executive Council. The Associate Dean chairs the committee. The Associate Director for Research serves on the Modelling Committee and the Assistant Director for Division of Physical Oceanography and Ocean Engineering serves on the Monitoring Committee. The Assistant Director for Division of Chemistry and Toxicology co-chairs the toxics subcommittee of STAC which is playing a key role in the development of the toxics strategy for the Bay. Institute personnel played key roles in the development of the Chesapeake Research Plan and the Living Resources commitments developed in 1987-88. Institute personnel continue to provide secretarial support for STAC through an agreement with the Chesapeake Research Consortium (CRC). The Institute provided the headquarters and staff (Director, Business Manager and Administrative support) for the Chesapeake Research Consortium until June 30, 1988. As of July 1, 1988, CRC headquarters moved to the University of Maryland's Chesapeake Biological Laboratory, Solomons, Maryland.

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Appendices

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APPENDIX I

Publications

JOURNAL AND BOOK CONTRIBUTIONS

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APPENDIX II

Faculty

FACULTY OF THE SCHOOL OF MARINE SCIENCE— JULY 1, 1987 TO JUNE 30, 1988

Gary F. **Anderson**, Instructor in Marine Science. B.S., Southampton College of Long Island University; M.A., the College of William and Mary. Physical Oceanography and Environmental Engineering.

Jay D. **Andrews**, Professor Emeritus of Marine Science. B.S., Kansas State College; M.A., Ph.D., University of Wisconsin. Marine Fisheries Science.

Herbert M. **Austin**, Professor of Marine Science. B.S., Grove City College; M.S., University of Puerto Rico; Ph.D., Florida State University. Marine Fisheries Science.

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Christopher S. **Welch**, B.S., Stanford University; Ph.D., Massachusetts Institute of Technology. NASA Langley Research Center.

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Lawrence L. **Wiseman**, A.B., Hiram College; M.A., Ph.D., Princeton University. Biology Department, the College of William and Mary.

Paul L. **Zubkoff**, B.S., University of Buffalo; M.A., George Washington University; Ph.D. Cornell University. Micro Science Consulting.

APPENDIX III

Financial Management And Administration

The Institute experienced another year of growth as reflected by the increase in cash expenditures of $800,000. The State-funded activity amounted to $9.9 million during 1988, as compared to $9.6 million during 1987.

The State approved the use of a financial program last year which required management to fine-tune the financial, budgetary and maximum employment levels associated with this new program of Financial Assistance for Education and General Program. The program is used to specifically identify externally-sponsored from State-sponsored research. This programmatic change highlighted a need for adjustments in the maximum employment level of the Institute. Approval of the resulting amendment request to the General Assembly for additional full-time equivalent positions will complete the administrative change designed to more adequately reflect the nature of Institute operations.

The second phase of the new accounting system software began by using the system on a daily basis to process all accounting transactions and produce management information reports. While the system is meeting basic accounting and managerial needs, additional training and learning continues on a daily basis to provide a better flow of information and to more fully utilize the system's capabilities.

The Institute's records for the preceding fiscal year (1987) were audited by the State's Auditor of Public Accounts (APA). The Institute continued to receive an unqualified opinion with a few management comments aimed at improving internal controls. The Defense Contract Audit Agency (DCAA) reviewed and approved the Institute's actual indirect cost rates for the fiscal years 1983-1987 as well as the proposed rates for fiscal years 1989 and 1990. Compliance with the government's requirements on these rates should facilitate the Institute's negotiations with federal contractors. The Internal Audit Office of the College of William and Mary reviewed the vessel operations and the revolving loan fund. The vessel audit revealed no material deficiencies, but offered numerous suggestions for improving fiscal operations. The revolving loan fund audit revealed no material deficiencies.

The Institute continued its participation in the State's Higher Education Equipment Trust Fund designed to provide supplemental funding for state-of-the-art educational and research equipment. The continuation of participation in this program is dependent upon meeting certain administrative and financial requirements. This year VIMS received $117,000 which was used to acquire a toxicology laboratory control and monitoring system, a wave recording device, a liquid scintillation counter, a high purity water system for chemistry/toxicology and a personal computer workstation. VIMS' total proceeds to date from this program are $181,000.

APPENDIX IIIa

Cash Expenditures

FISCAL YEAR—JULY 1, 1987 TO JUNE 30, 1988

RESEARCH PROGRAM AREAS	STATE FUNDS	SPONSORED RESEARCH	TOTAL
I. Investigate the fisheries of Virginia and factors affecting fluctuations in abundance.	$ 898,518	$1,206,542	$2,105,060
II. Investigate and define the distribution of benthic animals and communities and their interactions with the biological, physical and chemical environment.	65,810	251,846	317,656
III. Develop an understanding of plankton processes in the Chesapeake Bay system and Virginia coastal waters.	225,501	28,044	253,545
IV. Describe and evaluate the tidal freshwater ecosystems of Virginia's major rivers.	70,908	-0-	70,908
V. Investigate structure and function of mesohaline marshes and submerged aquatic vegetation.	217,045	55,839	272,884
VI. Study diseases of marine and estuarine organisms.	172,981	75,841	248,822
VII. Develop and perfect methods and techniques for economical culture of marine and estuarine organisms.	388,878	47,871	436,749
VIII. Determine the fate and effect of toxic chemicals in the Chesapeake Bay system.	800,218	308,679	1,108,897
IX. Study nutrient cycling processes and controls in riverine, estuarine and coastal marine environments.	117,981	47,490	165,471
X. Evaluate factors leading to, and the consequences of, nutrient enrichment.	103,604	92,170	195,774
XI. Understand the dynamics of benthic boundary layers and associated processes of sediment resuspension, transport, and animal-sediment interaction on coastal and estuarine environments.	199,782	21,226	221,008

XII.	Describe and understand the circulation of waters in the estuarine and coastal environment.	$ 398,292	$ 45,126	$ 443,418
XIII.	Develop a better understanding of shore-face, surf zone and beach processes.	47,299	190,280	237,579
XIV.	Describe and explain the late Quaternary sedimentology, stratigraphy and geological evolution of the Chesapeake Bay and coastal waters.	70,255	133,610	203,865
XV.	Conduct investigations related to the development, utilization, and management of resources of significance to the marine environment.	149,843	157,747	307,590
	Total Research	$3,926,915	$2,662,311	$6,589,226
MONITORING PROGRAM AREAS				
I.	Fisheries	$ 10,567	$ -0-	$ 10,567
II.	Plankton	9,728	40,587	50,315
III.	Bacteria (Lower York River)	-0-	13,234	13,234
IV.	Parasites and Pathogens	-0-	-0-	-0-
V.	Benthic Invertebrates	20,181	6,686	26,867
VI.	Estuarine Plant Communities	45,629	166,901	212,530
VII.	Coastal Erosion	-0-	117,184	117,184
VIII.	Physical and Chemical	27,980	244,628	272,608
	Total Monitoring	$ 114,085	$ 589,220	$ 703,305
Miscellaneous		$ 97,660	$ 8,544	$ 106,204
Advisory Services		$ 510,549	$ 522,491	$1,033,040
Education		$ 466,776	$ -0-	$ 466,776
	SUBTOTAL	$5,115,985	$3,782,566	$ 8,898,551
Support				
	Service Centers (net)	438,684	-0-	438,684
	Library	243,320	-0-	243,320
	General Administration	385,551	-0-	385,551
	Research and Academic Administration	833,736	-0-	833,736
	Financial Administration	1,165,264	-0-	1,165,264
	Physical Plant	1,172,318	-0-	1,172,318
	Other Institutional Activities	19,777	-0-	19,777
	Leave (scientific)	536,135	-0-	536,135
Total Support		$4,794,785	$ -0-	$4,794,785
GRAND TOTAL		$9,910,770	$3,782,566	$13,693,336

APPENDIX IIIb

Grants and Contracts Awarded

FISCAL YEAR—JULY 1, 1987 TO JUNE 30, 1988

FEDERAL FUNDING

Austin, H. M.; "Chesapeake Bay Stock Assessment Administrative Support," National Marine Fisheries Service, $22,010 (7/1/87 - 8/31/88).

Austin, H. M. and Erik Barth; "Commercial Fisheries Data Base," National Marine Fisheries Service, $52,890 (7/1/87 - 8/31/88).

Burreson, Eugene; "Assessment of MSX Resistance in Hatchery Reared Oysters," National Oceanic and Atmospheric Administration/Sea Grant, $15,889 (1/1/88 - 12/31/89).

Chittenden, Mark; "Baywide Trawling, Chesapeake Bay Stock Assessment," National Marine Fisheries Service, $236,400 (7/1/87 - 8/31/88).

Chu, Fu-Lin; "Fatty Acids in American Oysters," National Science Foundation, $3,880 (8/1/85 - 7/31/88).

Diaz, Robert J., and Linda Schaffner; "Aquatic Benthos Monitoring," Baltimore Army Corps of Engineers, $216,208 (5/15/87 - 12/31/88).

Diaz, Robert J.; "Studies Related to Low-Dissolved Oxygen in the Chesapeake Bay," National Oceanic and Atmospheric Administration/Sea Grant, $79,640 (9/1/87 - 12/31/88).

Diaz, Robert J.; "Thimble Shoals Evaluation," Norfolk Army Corps of Engineers, $4,774 (1/19/88 - 2/19/88).

DuPaul, William; "Marine Advisory Services, Sea Grant 1988," National Oceanic and Atmospheric Administration, $356,734 (1/1/88 - 12/31/88).

DuPaul, William and James E. Kirkley; "Sea Scallop Dredge Modifications," National Oceanic and Atmospheric Administration, $47,576 (1/1/88 - 12/31/88).

Hamrick, John; "Intergovernmental Personnel Agreement, 3-D Model," Vicksburg Army Corps, $6,090 (4/1/88 - 6/30/88).

Hardaway, Scott; "Chesapeake Bay Shoreline Erosion Study—Inventory Computer Data Base," Norfolk Army Corps, $9,998 (7/1/87 - 6/30/88).

Hershner, Carl; "Tidal Rivers Inventory," National Oceanic and Atmospheric Administration, $50,000 (11/1/87 - 9/30/88).

Kimball, Suzette; "Gravity Coring, Eastern Branch, Elizabeth River," Norfolk Army Corps, $5,875 (3/29/88 - 4/30/88).

Kuo, Albert; "Intergovernmental Personnel Agreement: Dredging Contaminated Sediment," Vicksburg Army Corps, $22,202 (4/1/88 - 9/30/88).

Loesch, Joseph G.; "Mark and Recapture Study of Striped Bass in the James River," National Marine Fisheries Service, $50,000 (2/1/88 - 1/31/89).

Loesch, Joseph G., and James Colvocoresses; "Striped Bass Monitoring," National Marine Fisheries Service, $120,000 (7/1/87 - 6/30/88).

Loesch, Joseph G.; "Striped Bass Tagging, Rappahannock River," National Marine Fisheries Service, $131,704 (9/15/87 - 9/14/88).

Loesch, Joseph G.; "Study of Alosa Stock Composition," National Marine Fisheries Service, $48,000 (2/1/88 - 1/31/89).

Lucy, Jon; "Catch Trends and Fish Utilization in Virginia's Offshore Recreational Pelagic Fisheries," U.S. Fish and Wildlife Service, $40,110 (1/16/88 - 1/15/89).

Lucy, Jon; "Development and Implementation of a Catch and Effort Data Collection System for Monitoring Virginia's Artificial Fishing Reefs," U.S. Fish and Wildlife Service, $30,227 (1/16/88 - 1/15/89).

Lynch, Maurice; "Environmental Trends Report," Council on Environmental Quality, $7,943 (11/5/87 - 6/30/88).

MacIntyre, William G.; Intergovernmental Personnel Agreement: Sorption/Organic Mixture Component," U. S. Air Force, $53,000 (6/1/86 - 7/31/88).

Mason, Patrice; "TEM/SEM Studies of NASA Material," National Aeronautic and Space Administration, $13,795 (9/20/87 - 9/25/88).

Meehan, Brian and H. M. Austin; "Electrophoretic Analysis of Weakfish, Bluefish, and Summer Flounder," U.S. Fish and Wildlife Service, $126,056 (4/7/88 - 3/31/89).

Musick, John A.; "Bottlenose Dolphin Statistics," National Marine Fisheries Service," $3,000 (11/5/87 - 1/31/88).

Musick, John A. and A. Deane Estes; "Stock Identification of Summer Flounder," U. S. Fish and Wildlife Service, $142,400 (8/16/88 - 8/15/89).

Neilson, Bruce; "Mainstem Monitoring, Chesapeake Bay," Environmental Protection Agency, $74,632 (10/1/86 - 3/31/88).

Nichols, Maynard; "Plume Monitoring of Rappahannock and York Spit Channels, Baltimore Harbor and Channels," Baltimore Army Corps of Engineers, $177,000 (4/27/87 - 12/31/88).

Norcross, Brenda; "Flounder Studies/Assistantship," National Marine Fisheries Service, $14,415 (7/1/87 - 8/31/88).

Orth, Robert J., and Jacques van Montfrans; "Role and Value of Shallow Water Habitats for Megalopae-Blue Crab," National Oceanic and Atmospheric Administration/Sea Grant, $37,361 (1/1/88 - 12/31/88).

Orth, Robert J.; "Submerged Aquatic Vegetation Abundance," Environmental Protection Agency, $30,000 (7/1/87 - 5/31/88).

Orth, Robert J.; "SAV Distribution and Abundance," National Oceanic and Atmospheric Administration, $30,000 (10/1/87 - 6/30/88).

Orth, Robert J.; "SAV Mapping, Chesapeake Bay," National Oceanic and Atmospheric Administration, $20,000 (10/1/86 - 9/30/88).

Schaffner, Linda; "Benthic Sampling, Baltimore Channels," Baltimore Army Corps

of Engineers, $392,635 (8/17/87 - 8/16/90).

Silberhorn, Gene S.; "Management of Wetlands: Enhanced Advisory Data Management," National Oceanic and Atmospheric Administration, $39,000 (10/1/87 - 9/30/88).

Silberhorn, Gene S.; "Management of Wetlands: Enhanced Marsh Inventory Program," National Oceanic and Atmospheric Administration, $8,000 (10/1/87 - 9/30/88).

Silberhorn, Gene S.; "Management of Wetlands: Permit Applications," National Oceanic and Atmospheric Administration, $4,000 (10/1/87 - 9/30/88).

Theberge, N. Bartlett; "Feasibility of Virginia's Assuming 404 Regulatory Authority," Environmental Protection Agency, $24,952 (10/20/87 - 10/19/88).

Wetzel, Richard; "Isotopic Determination of Nitrogen," National Oceanic and Atmospheric Administration/Sea Grant, $19,266 (1/1/88 - 12/31/88).

Wetzel, Richard; "Response and Stability of Eelgrass Communities," National Oceanic and Atmospheric Administration/Sea Grant, $27,180 (1/1/88 - 12/31/88).

COMMONWEALTH FUNDING

Bender, Michael; "Analysis of Kepone Samples," State Water Control Board, $17,025 (7/1/87 - 6/30/88).

Bender, Michael; "Effects of Suspended Solids on Uptake and Depuration of TBT by Oysters," State Water Control Board, $15,662 (7/1/87 - 6/30/88).

Bender, Michael; "Kepone Sample Analyses," State Water Control Board, $6,800 (7/1/87 - 6/30/88).

Bender, Michael; "Kepone Sample Analyses," State Water Control Board, $20,667 (6/1/88 - 6/30/89).

Bender, Michael; "Surface Microlayer Toxicity," State Water Control Board, $12,000 (7/1/87 - 6/30/88).

Diaz, Robert J.; "Protocol for Environmental Data: Emphasis on Benthos," State Water Control Board, $8,400 (7/1/87 - 6/30/88).

DuPaul, William and Christine Plummer; "Voluntary No Sewage Discharge," Virginia Department of Health, $18,685 (7/1/87 - 12/30/87).

Evans, David; "Equipment Grant," Council on the Environment, $2,255 (6/1/87 - 6/30/88).

Hardaway, Scott; "Joint Commonwealth Programs Addressing Shore Erosion in Virginia," Soil and Water Commission, $95,780 (7/1/86 - 6/30/87).

Hardaway, Scott; "Chesapeake Bay Shoreline Study," Department of Conservation and Historic Resources, $44,998 (7/1/87 - 6/30/88).

Hardaway, Scott; "Shoreline Erosion in Virginia," Department of Conservation and Historic Resources, $116,145 (7/1/87 - 6/30/88).

Hobbs, Carl H.; "Heavy Minerals Investigations," Department of Mines, Minerals, and Energy, $125,000 (7/1/87 - 6/30/88).

Huggett, Robert J.; "TBT Analyses," State Water Control Board, $7,257 (7/1/87 - 6/30/88).

Huggett, Robert J.; "TBT Monitoring in Marinas," State Water Control Board, $28,492 (7/1/87 - 6/30/88).

Kator, Howard I.; "Evaluation of Microbial Indicators," Department of Conservation and Historic Resources," $29,384 (10/1/87 - 8/31/88).

Kator, Howard I.; "Nitrification," State Water Control Board, $17,136 (7/1/87 - 6/30/88).

Kimball, Suzette; "Environmental Assessment of Sand Resource Sites, Lower Chesapeake Bay," Department of Conservation and Historic Resources, $10,000 (11/15/87 - 10/30/88).

Kimball, Suzette; "Nearshore Stockpile Areas," Department of Conservation and Historic Resources, $27,786 (12/1/87 - 11/30/88).

Lawrence, F. Lee; "Marine Science Mentorship Program," Virginia Department of Education, $5,094 (6/1/88 - 12/31/88)

Musick, John A.; "Marine Mammals," Department of Game and Inland Fisheries, $50,000 (7/1/87 - 6/30/88).

Musick, John A.; "Sea Turtles Ecology," Department of Game and Inland Fisheries, $56,550 (7/1/87 - 6/30/88).

Neilson, Bruce; "Field Studies at Oyster Slip," State Water Control Board, $6,786 (7/1/87 - 6/30/88).

Neilson, Bruce; "Rappahannock River Hypoxia Study," State Water Control Board, $22,100 (7/1/87 - 6/30/88).

Neilson, Bruce; "Sediment Processes," State Water Control Board, $29,107 (7/1/87 - 6/30/88).

Roberts, Morris H., Jr.; "Toxicity of Natural Waters to Bivalve Larvae," State Water Control Board, $12,623 (7/1/87 - 6/30/88).

PRIVATE FUNDING

Bender, Michael; "Field Monitoring Studies," Chesapeake Corporation, $54,010 (4/1/88 - 3/31/89).

Chu, Fu-Lin; "Algae Samples," State University of New York, $294 (4/1/88 - 4/30/88).

Diaz, Robert J.; "Radiological Sampling," Newport News Shipbuilding and Dry Dock, $7,024 (7/1/87 - 7/31/87).

Diaz, Robert J.; "Radiological Sampling," Newport News Shipbuilding and Dry Dock, $7,600 (6/15/88 - 7/31/88).

Diaz, Robert J.; "York River Environmental Assessment," Resource Applications, $5,000 (9/21/87 - 10/31/87).

Haas, Leonard; "Microscope Techniques Comparison," Virginia Environmental Endowment, $9,100 (9/1/87 - 8/31/88).

Huggett, Robert J.; "TBT Analysis," State of Hawaii, $4,000 (10/13/87 - 12/31/87).

Huggett, Robert J.; "TBT Surface Water Samples," New York State Department of Environmental Conservation, $1,070 (7/2/87 - 7/31/87).

Kimball, Suzette; "Environmental Assessment of Sand Resource Sites Lower Chesapeake Bay," City of Hampton, $28,189 (11/15/87 - 10/30/88).

Lipcius, R. N.; "Spiny Lobster Restoration, Si'an Ka'an Province, Mexico," Earthwatch, $590 (7/1/87 - 7/31/87).

Lynch, Maurice; "Chesapeake Research Consortium, Cooperative Agreement," Chesapeake Research Consortium, $40,050 (10/1/87 - 10/30/88).

Lynch, Maurice; "Cooperative Agreement Graduate Student Support," Scientific Environmental Associates, $9,486 (10/1/87 - 9/30/88).

Mann, Roger; "Anti-Fouling Paint Study," Rockland, Inc. $2,000 (7/22/87 - 7/30/87).

Mann, Roger; " Oyster Ground Survey in the James River," Newport News Shipbuilding and Dry Dock", $5,000 (12/1/87 - 1/31/88).

Mann, Roger; "Uptake and Depuration of Biological Toxins by Bivalves," Booz, Allen and Hamilton, $33,470 (1/1/88 - 12/31/88).

Mason, Patrice; "TEM/SEM Studies," Huntsman Chemical Corporation, $1,330, (7/1/87 - 6/30/88).

Meehan, Brian and H. M. Austin; "Analysis of Stock Structure of the Weakfish within Atlantic Coastal Waters," Atlantic States Marine Fisheries Commission, $88,750 (3/1/88 - 2/28/90).

Musick, John A.; "Empress II Field Observations," University of Maryland Center for Environmental and Estuarine Studies, $52,575 (11/1/87 - 11/30/88).

Neilson, Bruce; "Sediment Oxygen Demand," HDR Corporation, $13,000 (8/18/87 - 11/30/87).

Neilson, Bruce;"Recalibration of the Pagan River Water Quality Model," Smithfield Foods, $44,430 (1/7/88 - 8/31/88).

Orth, Robert J.;"Submerged Aquatic Vegetation Mapping," Maryland Department of Natural Resources, $30,000 (11/15/88 - 7/1/89).

Ruzecki, Evon; "I-664 Interchange Current Measurements," Morrison-Knudsen/Interbetan $30,000 (7/1/87 - 9/30/87).

Silberhorn, Gene S.; "Aerial Photography, Isle of Wight County," County of Isle of Wight, $7,253 (10/10/87 - 4/10/88).

Continuing Grants and Contracts

FISCAL YEAR—JULY 1, 1987 TO JUNE 30, 1988

FEDERAL FUNDING

Austin, Herbert, Mark Chittenden; "Chesapeake Bay Stock Assessment," National Marine Fisheries Service, $337,724 (7/1/86 - 8/31/89).

Chu, Fu-Lin; "Fatty Acids in the American Oyster," National Science Foundation, $90,000 (8/1/85 - 7/31/88).

Chu, Fu-Lin and Beverly Anne Weeks; "Investigation of Acquired Immunity Adaptive Response in the American Oyster," Sea Grant/National Oceanic and Atmospheric Administration, $35,247 (1/1/87 - 3/31/88).

Diaz, Robert J. and Linda Schaffner; "Baltimore Channels, Benthic Monitoring," Baltimore Army Corps of Engineers, $216,208 (5/17/87 - 1/31/88).

DuPaul, William; "Marine Advisory Services," Sea Grant/NOAA, $421,006 (1/1/87 - 3/31/88).

DuPaul, William; "Sea Scallop Research," Sea Grant/NOAA, $9,135 (4/1/87 - 3/31/87).

Ellis, Lehman; "Cryopreservation of Commercially Important Marine Bivalves Gametes and Larvae," Sea Grant/NOAA, $29,181 (1/1/87 - 12/31/87).

Gammisch, Robert; "Side-Scan Sonar of Artificial Reef Sites," U. S. Fish and Wildlife Service, $3,730 (8/8/86 - 8/8/87).

Hargis, William J., Jr.; "Fish Pathology Studies," Sea Grant/NOAA, $18,000 (3/1/87 - 12/31/87).

Hargis, William J., Jr.; "Ulcerative Disease Syndrome Committee," Sea Grant/NOAA, $735 (5/1/87 - 12/31/87).

Huggett, Robert J.; "Bay Monitoring/Sediment," Environmental Protection Agency/State Water Control Board, $7,930 (1/1/86 - 11/30/87).

Huggett, Robert J.; "TBT Analysis," Department of the Navy, Weyher/Livesey, $13,800 (3/15/87 - 9/30/87).

Kator, Howard; "Shellfish Workshop," Sea Grant/NOAA, $10,000 (1/1/86 - 7/31/88).

Kator, Howard and Martha W. Rhodes; "Bacterial Counts in Shellfish Growing Area," NOAA, $28,650 (10/1/86 - 9/30/87).

Kimball, Suzette; "Interpersonnel Agreement," Vicksburg Army Corps of Engineers, $8,536 (4/30/87 - 4/30/88).

Lipcius, R. N.; "Interactive and Non-Linear Effects of Predation," National Science Foundation, $80,936 (4/1/87 - 9/30/89).

Loesch, Joseph G.; "Mark and Recapture Study of Striped Bass in the James River," National Marine Fisheries Service, $50,380 (5/1/87 - 4/30/88).

Loesch, Joseph, James Colvocoresses, and William Kriete; "Striped Bass Abundance in Virginia," National Marine Fisheries Service, $119,568 (8/1/86 - 7/31/87).

Loesch, Joseph, and William Kriete; "Assessment of Commercial Fishing Effort in Virginia," National Marine Fisheries Service, $26,600 (11/1/86 - 12/31/87).

Loesch, Joseph, and William Kriete; "Striped Bass Stocking Experiment on the Pamunkey River," U. S. Fish and Wildlife Service, $27,316 (3/1/87 - 2/28/88).

Lucy, Jon; "Catch Trends in Offshore Recreational Fishery," U. S. Fish and Wildlife Service, $32,265 (8/8/86 - 12/31/87).

Lucy, Jon; "Evaluating Catch Data on Artificial Reefs," U. S. Fish and Wildlife Service, $23,920 (7/29/86 - 12/31/87).

MacIntyre, William G.; "Sorption, Organic Mixture Components," Air Force Office of Sponsored Research, $35,000 (6/1/87 - 7/31/88).

Mann, Roger; "Influence of Low Oxygen Tension on Oysters," Sea Grant/National Oceanic and Atmospheric Administration, $21,999 (9/1/86 - 12/31/87).

Meehan, Brian and Herbert Austin; "Stock Identification Using Electrophoretic Analysis," U. S. Fish and Wildlife Service, $202,805 (7/29/86 - 3/31/88).

Musick, John A.; "Stock Identification, Flounder Mark and Recapture," U. S. Fish and Wildlife Service, $104,845 (8/8/86 - 8/16/87).

Musick, John A.; "A Summary of Lift and Drag and Related Drag Reducing Mechanism in Fishes," NASA, $20,000 (11/84 - 10/87).

Nichols, Maynard and Robert J. Diaz; "Plume Monitoring of Rappahannock and York Spit Channels," Baltimore Army Corps of Engineers, $177,000 (4/7/87 - 12/31/88).

Neilson, Bruce; "Bay Monitoring," Environmental Protection Agency, $240,114 (10/1/86 - 11/30/87).

Norcross, Brenda and Herb Austin; "Characterization of the Relationship between Seasonal Wind Regimes and the Recruitment of Croaker and Flounder," Sea Grant/NOAA, $19,082 (1/1/87 - 12/31/87).

Orth, Robert J.; "Distribution of Sub-Aquatic Vegetation," NOAA, $6,000 (10/1/86 - 9/30/87).

Orth, Robert J. and Jacques van Montfrans; "Value of Shallow Water Habitats for Early Stages of Blue Crab," Sea Grant/NOAA, $46,326 (1/1/87 - 12/31/87).

Webb, Kenneth; "Is Phosphorous Removal an Efficient/Effective Chesapeake Bay Management Practice?," NOAA, $45,000 (10/1/86 - 9/30/87).

Wetzel, Richard; "Response and Stability of Eelgrass Communities in Chesapeake Bay," Sea Grant/NOAA, $22,326 (1/1/87 - 12/31/87).

Wright, L. D.; "Bed Response of Mid-Shoreface to Wind Events," National Science Foundation, $65,197 (1/15/87 - 12/31/88).

COMMONWEALTH FUNDING

Bieri, Rudolf; "Pilot Toxics," State Water Control Board, $213,827 (11/1/86 - 6/30/88).

Boon, John; "Evaluation of Sediment Dynamics and the Mobility of Heavy Minerals," Dept. of Mines, Minerals and Energy (Minerals Management Services), $23,635 (3/1/87 - 12/31/88).

Hobbs, Carl H.; "Fossilized Oyster Shell, Pocomoke Sound," Virginia Marine Resources Commission, $5,682 (7/1/87 - 6/30/89).

Lawrence, F. Lee; "The Bay Team," Council on the Environment, $150,000 (7/1/86 - 6/30/88).

Hobbs, Carl; "Assessment of Economic Heavy Minerals," Virginia Division of Mineral Resources, $40,000 (4/1/86 - 12/31/87).

PRIVATE FUNDING

Barrick, Susan; "Update and Maintain Chesapeake Bay Bibliography," Maryland Department of Natural Resources, $25,000 (6/85 - 11/87).

Bender, Michael; "Summer Research Aide Program," Virginia Environmental Endowment, $12,000 (1/1/87 - 9/30/88).

Diaz, Robert J. and Linda Schaffner; "Fowl River Benthic Profiling," Taxonomic Associates, $61,795 (5/15/87 - 12/31/87).

Diaz, Robert J. and Linda Schaffner; "Sediment Profiling, Long Island Sound," Evans and Hamilton, $18,000 (5/15/87 - 12/31/87).

Ellis, Lehman; "Establishment of Oyster Cell Lines," Jeffress Memorial, $35,000 (1/1/86 - 12/31/88).

Hershner, Carl and Jim Perry; "Endangered Plant Survey," Virginia Natural Heritage Program, $1,800 (5/27/87 - 11/30/88).

Kator, Howard; "Shellfish Pathogen Indicators," Technion International, Inc., $31,496 (7/7/86 - 9/30/87).

Lipcius, R.N.; "Experimental Ecology of Spiny Lobsters in the Mexican Caribbean," State University of New York, $12,535 (3/15/87 - 3/15/89).

Lipcius, R.N.; "Ecology of Juvenile Spiny Lobster and Conch at Lee Stocking Island-Bahamas," Caribbean Marine Research Center, $8,600 (1/1/87 - 12/31/87).

Lynch, Maurice; "Cooperative Agreement/Graduate Student," Scientific Environmental Associates, $9,274 (10/1/86 - 9/30/87).

Mason, Patrice; "Inspection of Styrofoam Samples," Huntsman Chemical Corporation, $1,800 (7/1/86 - TBA).

Musick, John A.; "Empress Study/Sea Turtle Census," University of Maryland Center for Environmental and Estuarine Studies, $109,995 (4/25/87 - 7/31/87).

APPENDIX IV

VIMS Seminar Summary

FISCAL YEAR—JULY 1, 1987 TO JUNE 30, 1988

NAME	DATE	TITLE
Dr. L.D. Wright VIMS	7/02/87	MUDS: Results of the Second Bohai Cruise, China
Mr. Douglas Huggett VIMS Graduate Student	7/20/87	Trophic Resource Analysis of Benthic Macrofauna of the Lower Bay
Mr. Michael Armstrong VIMS Graduate Student	7/24/87	Life History of Goosefish (*Lophius americanus*)
Mr. Brian Bowen VIMS Graduate Student	7/24/87	MT DNA Analysis of White Perch (*Morone americana*) Populations in Lower Chesapeake Bay
Mr. Clifford Ryer VIMS Graduate Student	8/04/87	Pipefish Foraging in Simulated Seagrass Habitats
Drs. Barry F. Sherr and Evelyn B. Sherr University of Georgia Marine Institute Sapelo Island, GA	8/17/87	Trophic Interactions in Pelagic Microbial Food Webs. I. Protozoan Bacterivory II. Speculations about Cybernetic Regulation of Carbon-Energy Flow in Pelagic Food Webs
Dr. Bernard Hsieh MD Department of Natural Resources Annapolis, MD	8/21/87	Simulation and Control of Estuary Water Quality Due to Regulated River Flow
Dr. William G. MacIntyre VIMS	10/08/87	My Groundwater Research Sabbatical with the USAF and a Proposal to Measure Groundwater (Non-Point) Sources of Organic Chemicals and Nutrients to Chesapeake Bay
Dr. Per Jonsson Natl. Swedish Environment Protection Board Solna, Sweden	10/21/87	Long-Term Research Results on Environmental Impact of Pulp Mills (Chemistry and Biology)
Prof. John Simpson Univ. of Wales United Kingdom	10/22/87	Shallow-Water Fronts: Formation and Structure Introductory Lecture in a Series on Physical Structure and Biological Implications in Shelf and Estuarine Waters
Dr. William G. MacIntyre VIMS	10/29/87	The Highlands of Scotland and the Hebrides—Sheep and Celts
Prof. John Simpson Univ. of Wales United Kingdom	10/30/87	Frontal Dynamics and Circulation Density Field. Baroclinic Jet? Instabilities. Eddy Scales. Transverse Circulation. Models with Friction

Dr. Richard Fralick and Mr. Frank Haw Northwest Marine Technology Shaw Island, WA	10/30/87	Advances in Marking Fish and Other Aquatic Animals
Prof. John Simpson Univ. of Wales United Kingdom	11/03/87	Biological Implications of Tidal Stirring Mixed, Stratified and Frontal Regimes. Enhanced Production at Fronts? Island Stirring and its Effect on Nutrient Budget.
Prof. John Simpson Univ. of Wales United Kingdom	11/05/87	Application of Mixing Models to Estuarine Environments. Freshwater Buoyancy Input. Stabilizing Influence of Estuarine Circulation.Conditions for Permanent, and for Periodic, Stratification.
Ms. Rebecca J. Savage VIMS Graduate Student	11/13/87	Modes of Longshore Variability in the Development of a Bar—Trough Morphology
Mr. Chang S. Kim VIMS Graduate Student	11/16/87	Interaction of Long Waves and Nearshore Barred Topography—A Mechanism of Bar Migration
Prof. A.J. Bowen Dalhousie Univ. Halifax, Nova Scotia Canada	11/16/87	Sediment Transport and Beach Equilibrium: Models, Dammed Models, and Statistics
Mr. Mohamed Zaki Moustafa VIMS Graduate Student	11/20/87	Advance Turbulence Closure Models and Their Application to Buoyant and Non-Buoyant Flows
Mr. Steven A. Skrabal VIMS Graduate Student	11/23/87	Clay Mineral Distributions and Source Discrimination of Holocene Sediments, Lower Chesapeake Bay
Dr. Eileen E. Hofmann Old Dominion Univ. Norfolk, VA	11/23/87	Models of Plankton Dynamics on the S. Eastern U.S. Continental Shelf
Dr. J. Schoer Technical University of Hamburg Hamburg, West Germany	11/24/87	Determination of the Origin of Suspended Material and Sediments in the Elb Estuary by Natural (Chemical) Tracers
Mr. Malcolm O. Green VIMS Graduate Student	12/14/87	Low-Energy Bedload Transport by Combined Wave and Current Flow on a Southern Mid-Atlantic Bight Shoreface
Ms. Tracy Eanes Skrabal VIMS Graduate Student	12/14/87	System Response of a Nourished Beach in a Low-Energy Estuarine Environment, Gloucester Point Virginia
Mr. Richard A. Byles U.S. Fish and Wildlife Service Albuquerque, NM	12/16/87	The Ecology and Behavior of Sea Turtles in Virginia
Dr. Peter C.H. Pritchard Florida Audubon Society Maitland, FL	12/16/87	The Leatherback: A Most Unusual Turtle
Dr. Linden Lee Office of Wetlands Protection U.S. EPA Washington, D.C.	12/17/87	Nontidal Wetland Delineation: Comparison of the Federal Methodologies
Ms. Sarah Bellmund VIMS Graduate Student	12/17/87	Assessing Environmental Stress on Juvenile Loggerhead Sea Turtles, *Caretta caretta*, in Virginia Waters
Dr. Tom Wilson SUNY Stony Brook, NY	12/22/87	Machine Vision and Digital Image Analysis: A Powerful New Tool for Biological Oceanography
Mr. Richard Cloutier Univ. of Kansas Lawrence, KS	1/07/88	Coelacanth Study Seminar Phylogenetic Interrelationships of Coelacanths (Actinistia)
Mr. Robert Griffith Southeastern Mass. University Boston, MA	1/07/88	Coelacanth Study Seminar Film-Live Coelacanth Collected in 1972 in The Comoros
Mr. R.W. Chapman Johns Hopkins Univ. Baltimore, MD	1/07/88	Coelacanth Study Seminar Mitochondrial DNA Variation in Population Species and Higher Taxa Analysis

Mr. Martin Posey Environm. Research Ctr. Edgewater, MD	1/27/88	Importance of Species Introduction in Marine Communities: the Example of the Introduced Seagrass *Zostera japonica*
Mr. Michael A. Unger VIMS Graduate Student	1/29/88	Fate of TBT in the Estuarine Environment
Ms. Bernardita Campos VIMS Graduate Student	2/19/88	Swimming Responses of Larvae of Three Mactrid Bivalves to Different Salinity Gradients
Ms. Carrollyn Cox VIMS Graduate Student	3/10/88	Seasonal Changes in Fecundity of Oysters, *Crassostrea virginica* from four Reefs in the James River, Virginia
Mr. Robert C. Siegfried VA Water Control Board Richmond, VA	3/18/88	Documentation of Daily Rings in the Otoliths Young-of-the-Year Spot, *Leiostomus xanthurus* and Atlantic Croaker, *Micropogonias undulatus*
Prof. F. F. Snelson, Jr. Univ. of Central Florida Orlando, FL	4/04/88	Biology of Dasyatid Rays in Florida Coastal Lagoons
Mr. Adam Frisch VIMS Graduate Student	4/11/88	Development, Test and Application of a New Method of Particle Shape Analysis Based on the Concept of the Fractal Dimension
Mr. Gary Johnson Ms. Rae Jean Sielen Biosonics, Inc. Seattle, WA	4/14/88	A Review of Hydroacoustic Technology for Fisheries Assessment and Management: A Presentation of Case Studies
Mr. Peter F. DeLisle VIMS Graduate Student	4/14/88	The Effects of Salinity on Cadmium Toxicity to the Bay Mysid, *Mysidopsis bahia* Molenock
Dr. Robert Holman Oregon State University Corvallis, OR	4/22/88	The Nearshore Wave Guide
Mr. Francois Espourteille VIMS Graduate Student	4/25/88	An Assessment of Tributyltin Contamination in Sediments and Shellfish in the Chesapeake Bay
Ms. Mary Sue Jablonsky-Moustafa VIMS Graduate Student	4/29/88	Swash Induced Zonation of a Foreshore Sediment Size Distribution
Ms. Rebecca M. Dickhut Univ. of Wisconsin-Madison Madison, WI	5/03/88	Chemical Fate Assessment and the Influence of Cosolvents on Hydrophobic Contaminant Solubility
Dr. John A. Musick VIMS	5/04/88	Ecology and Conservation of Sea Turtles in Virginia
Dr. Donald Swift Old Dominion Univ. Norfolk, VA	5/05/88	Mixed Layer Dynamics and Stratiformation on Shallow Sea Floors: Reconnaissance of the Atlantic Shelf
Ms. RuthEllen C. Klinger-Bowen University of Georgia Athens, GA	5/06/88	Age and Growth of Juvenile Loggerheads (*Caretta caretta*) from Chesapeake Bay
Mr. Erik Zobrist VIMS Graduate Student	5/06/88	The Influence of Post-Settlement Mortality on Recruitment Patterns in a Soft-Bottom Habitat
Mr. David Eggleston VIMS Graduate Student	5/26/88	Predator-Prey Dynamics Between the Blue Crab, *Callinectes sapidus* (Rathbun) and Juvenile Oysters, *Crassostrea virginica* (Gmelin)
Dr. William J. Wiseman Louisiana State Univ. Baton Rouge, LA	6/03/88	Hydrography of the Louisiana-Texas Continental Shelf
Ms. Carol Furman VIMS Graduate Student	6/03/88	Mitochondrial DNA Variation in Striped Bass, *Morone saxatilis*, from the Rappahannock River, Virginia
Mr. Daniel Hepworth VIMS Graduate Student	6/16/88	Response of a Partially Mixed Coastal Plain Estuary to Storm Events

APPENDIX V

VIMS Associates

The VIMS Associates provides an avenue for private individuals and organizations interested in preserving the quality of the marine environment to support the work performed at the Virginia Institute of Marine Science. Through their gifts the members of the Associates play an active role in continuing the vitality of the Institute and advancing its service to the Commonwealth of Virginia and the nation.

The faculty, staff and students gratefully recognize the generous support of the following individuals and organizations during 1987-1988.

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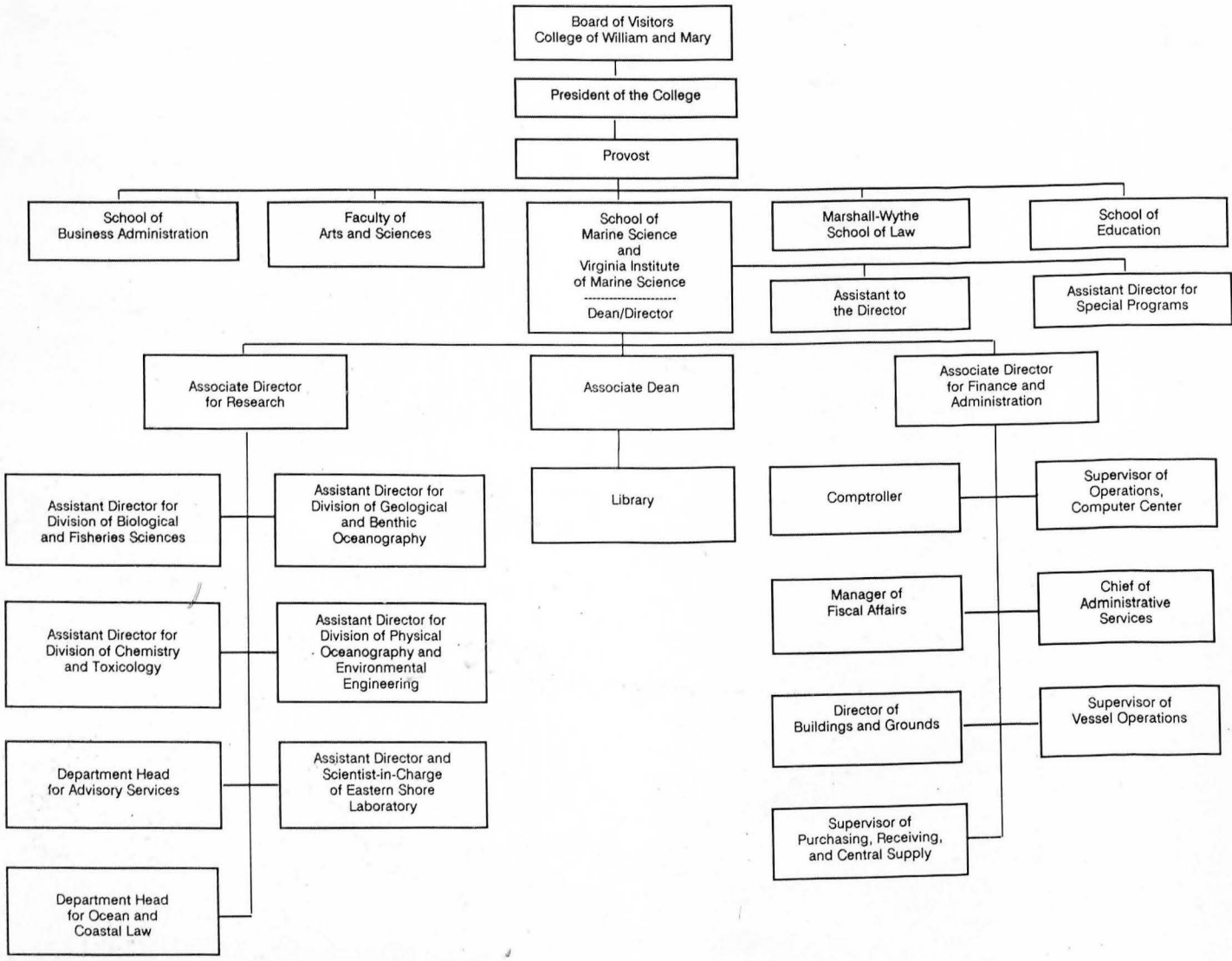
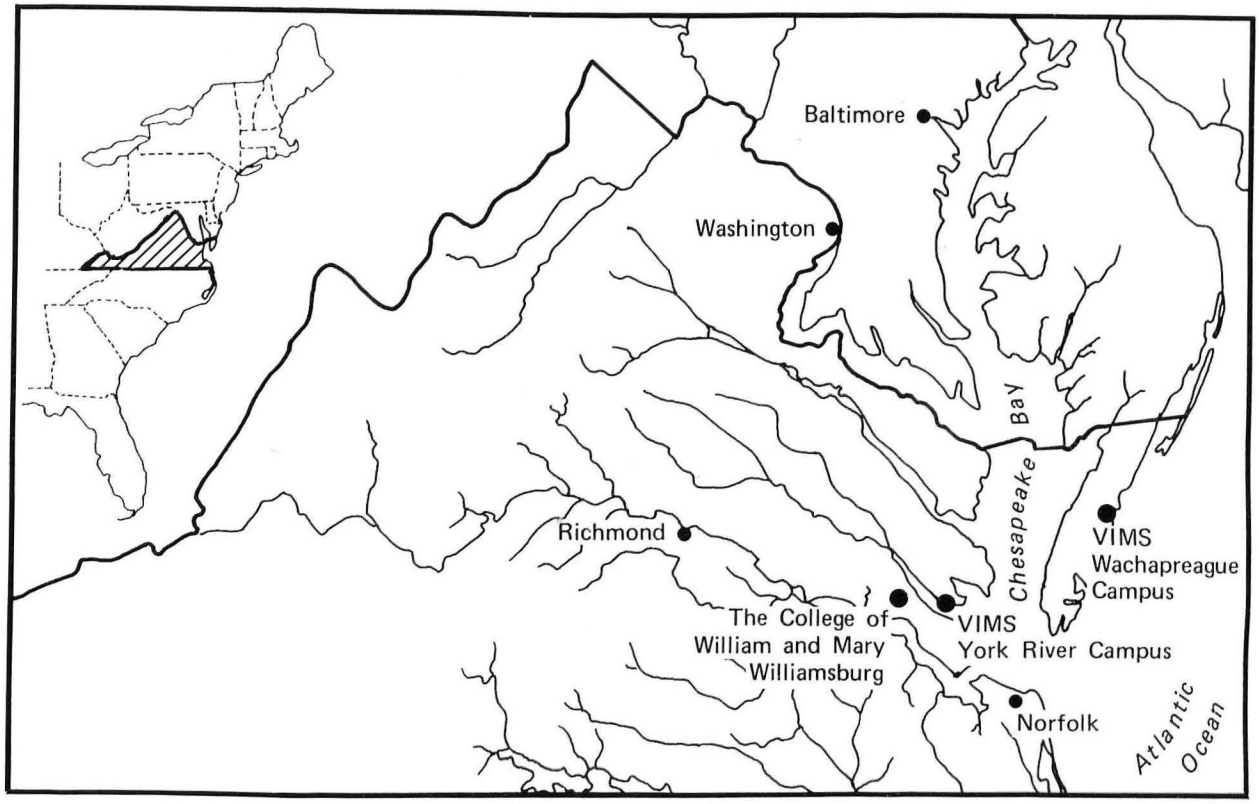
APPENDIX VI

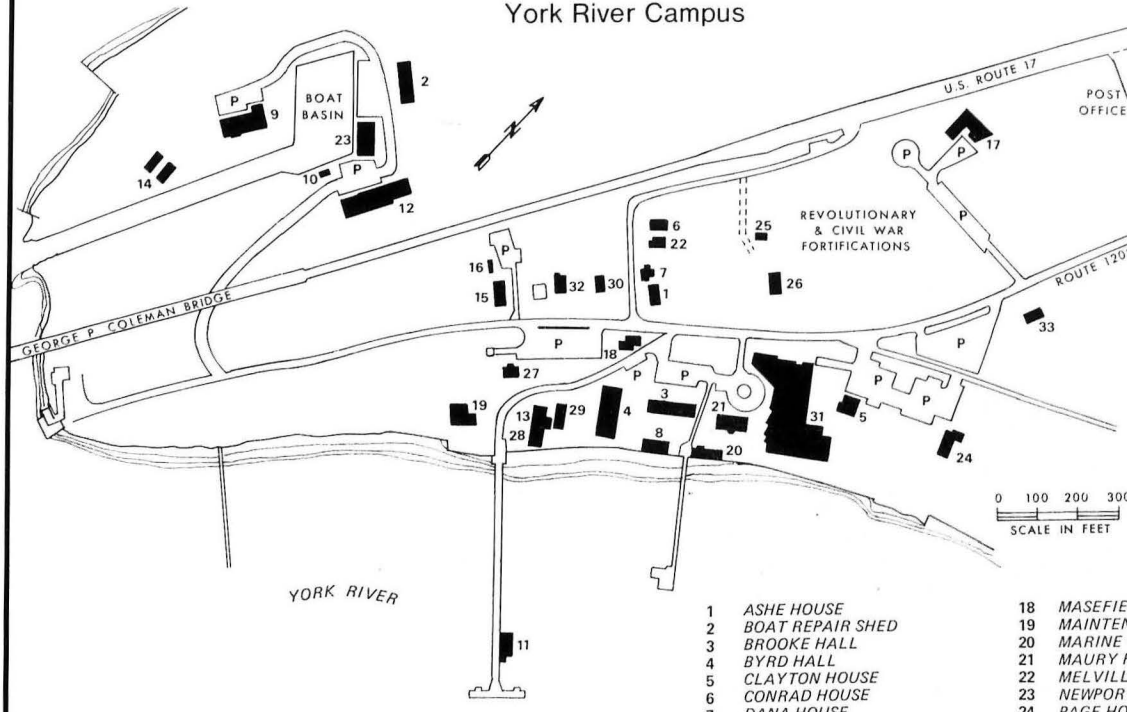
Organization

The Virginia Institute of Marine Science / School of Marine Science under the direction of the Dean / Director is organized to fulfill its triple mission of research, education and advisory services. The institutional organization reflects an emphasis on research and the provision of timely advice on matters related to utilization of the Commonwealth's marine resources.





Map of
York River Campus



1 ASHE HOUSE	18 MASEFIELD HOUSE
2 BOAT REPAIR SHED	19 MAINTENANCE SHOP
3 BROOKE HALL	20 MARINE CULTURE LAB
4 BYRD HALL	21 MAURY HALL
5 CLAYTON HOUSE	22 MELVILLE HOUSE
6 CONRAD HOUSE	23 NEWPORT HALL
7 DANA HOUSE	24 PAGE HOUSE
8 DAVIS HALL	25 POOL CAR GARAGE
9 DEMONSTRATION BUILDING	26 RALEIGH HOUSE
10 DIVING LOCKER	27 REED HOUSE
11 FERRY PIER HOUSE	28 SALT WATER LAB
12 FRANKLIN HALL	29 SEDIMENT LAB
13 GARAGE	30 STEVENSON HOUSE
14 GREENHOUSES	31 WATERMEN'S HALL
15 HOXTON HALL	32 WHITE HOUSE
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In Memoriam

Thomas A. Chapman
1925 - 1988

Mr. Thomas A. Chapman, Supervisor of Maintenance in the Department of Buildings and Grounds, retired as of March 1, 1988, after more than thirty-two years of service to the Institute and the Commonwealth of Virginia. His service included involvement in the construction or rehabilitation of every one of the Institute's buildings at Gloucester Point. His broad knowledge of the maintenance trades, his eagerness to help the scientific staff, and his cheerful demeanor made him a valuable asset to the Institute.

Subsequent to his retirement, Mr. Chapman passed away on April 16, 1988. He is greatly missed both professionally and personally by his many friends and colleagues at the Institute.

William H. Kriete, Jr.
1943 - 1988

William H. Kriete, Jr. arrived at VIMS in 1967 after graduation earlier that year from Lynchburg College. After temporarily serving as mate on the research vessel PATHFINDER, he was employed by the Fisheries Department on the shad and river herring (*Alosa*) project and shortly thereafter on striped bass research. His practical abilities as an excellent mechanic and at boat handling, together with a good working knowledge of Virginia waters, were recognized by his also serving as relief captain on the R/V PATHFINDER in those early years at VIMS, an unusual vote of trust for someone so young. Billy's first publication in 1970 dealt with the winter gill net fishery for striped bass in the Rappahannock River, and this research benefited greatly from his particularly close knowledge of that river and its watermen. He continued and intensified his interest in the anadromous fishes and in techniques of sampling them, persisting in studies of shad, herrings and striped bass throughout his 21 years at VIMS. He produced numerous peer-reviewed publications, wrote and assisted on a long string of annual contract reports, and presented research results and progress at meetings of the Virginia Academy of Sciences, the American Fisheries Society and the Estuarine Research Federation. His efforts and cheerful presence are sorely missed by his former coworkers and a multitude of good friends.